TISA Working Group Report

CERES TISA Sublead: D. Doelling

TISA: D. Keyes, C. Nguyen, M. Nordeen, R. Raju, M. Sun, F. Wrenn

GEO calibration: R. Bhatt, C. Haney, B. Scarino, A. Gopalan

GEO processing: K. Khlopenkov, R. Palikonda, D. Spangenberg

Sub-setter: C. Chu, E. Heckert, C. Mitrescu, P. Mlynczak

20th CERES Science Team Meeting

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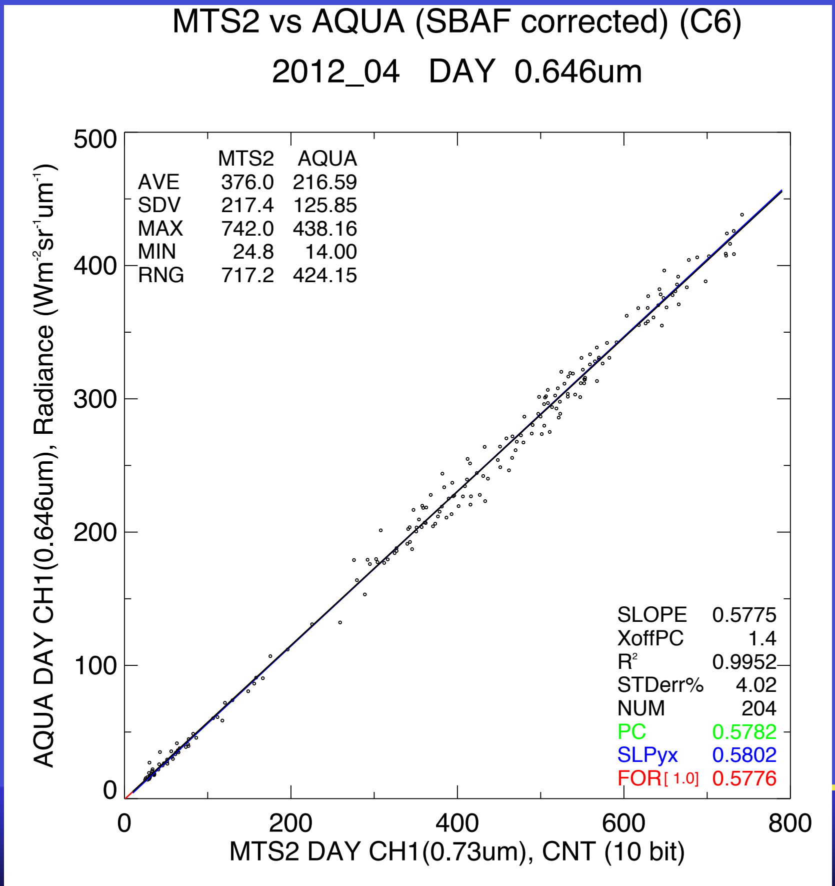
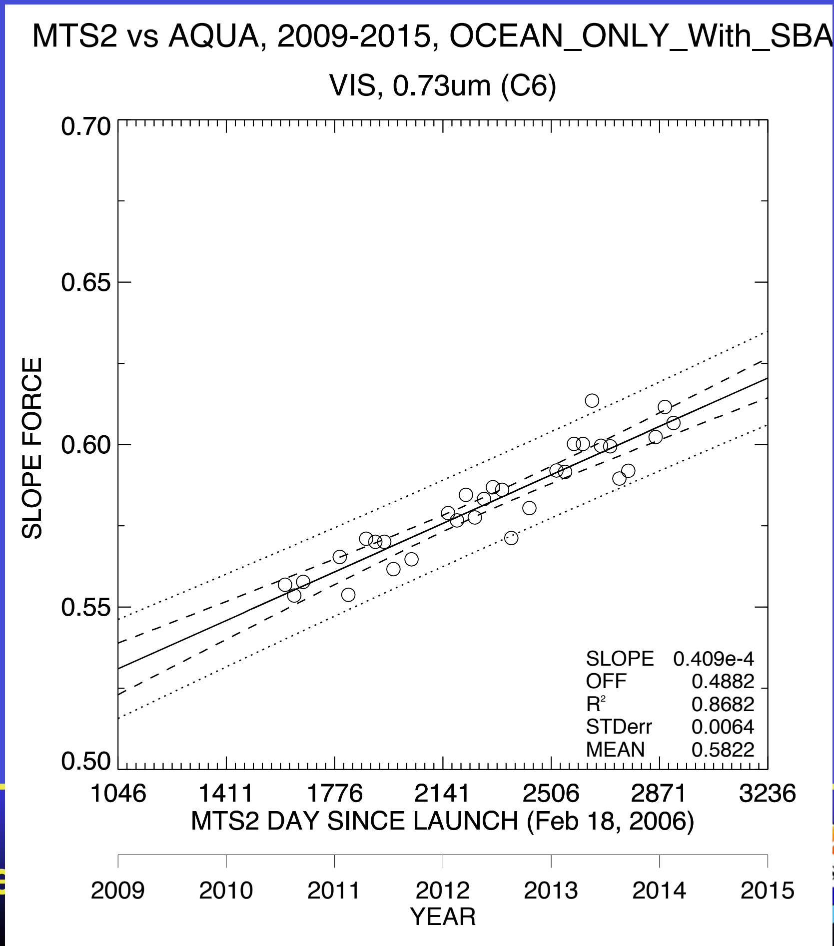
MTSAT-2/Aqua-MODIS raymatching

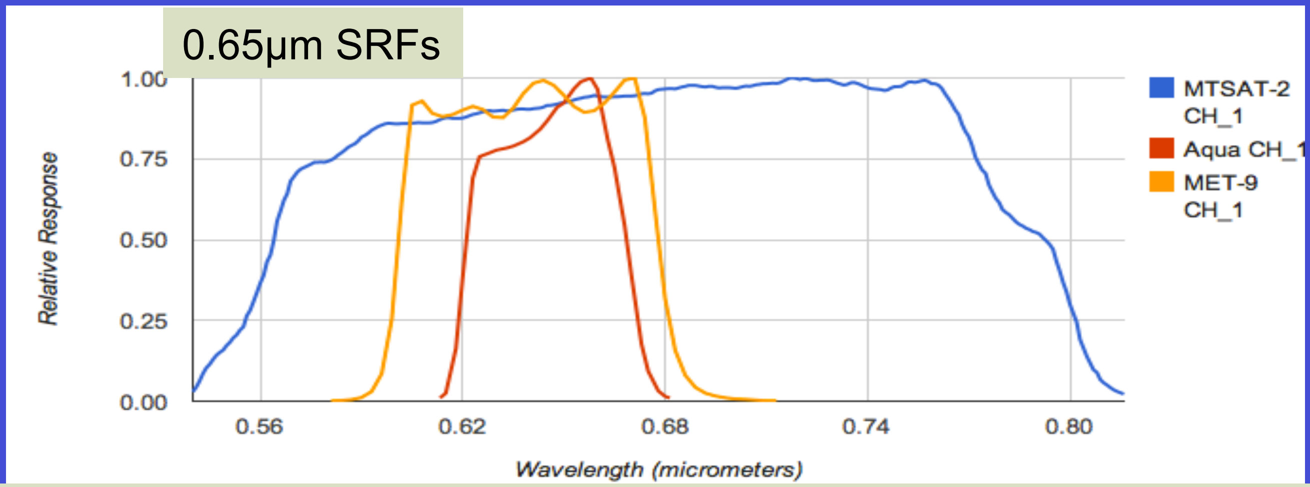
(CERES GEO visible calibration technique)

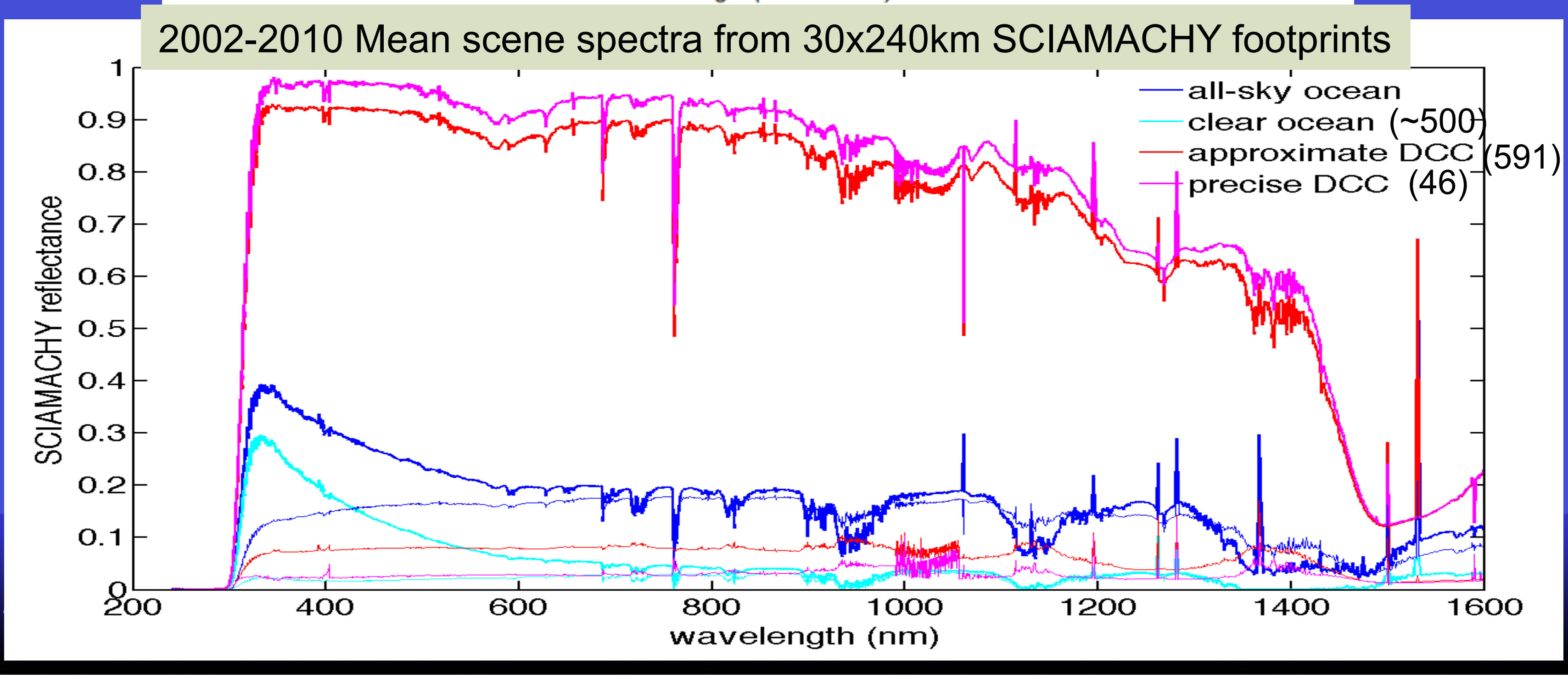
- 0.5° lat/lon grid MTSAT-2 and Aqua-MODIS 0.65 radiances over MTSAT equatorial domain
- Linearly regress coincident and angular matched monthly the MTSAT-2 and MODIS radiance pairs
- Monitor the slope over the lifetime of MTSAT-2
- The basis of the GEO Edition 4 calibration coefficients (Finalized Nov. 2013)





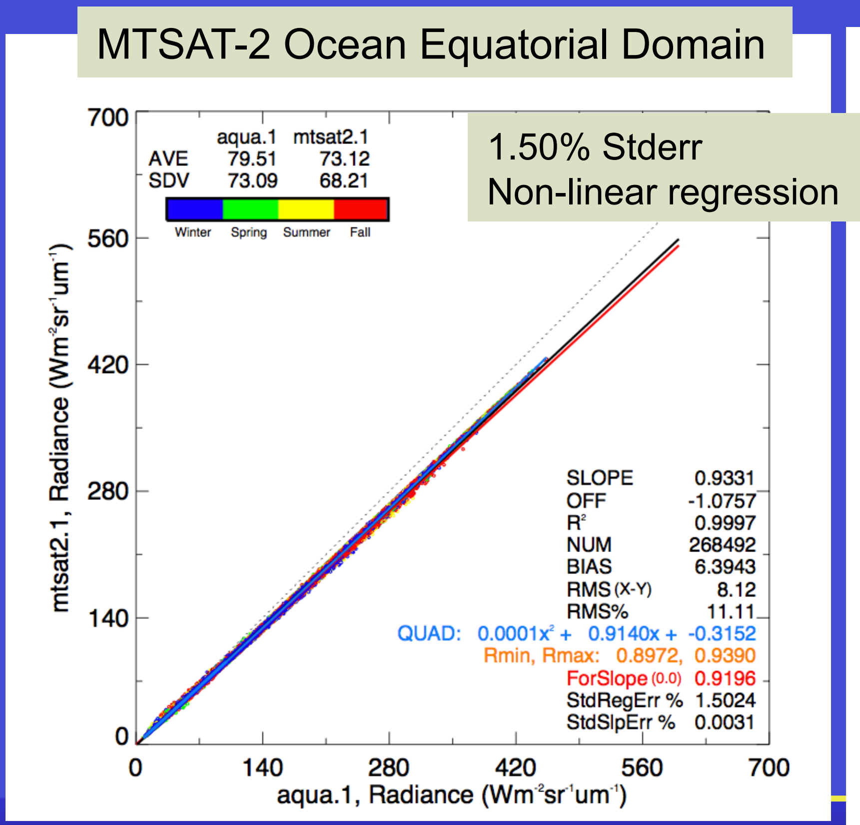
Scene spectra and spectral response functions (SRF)

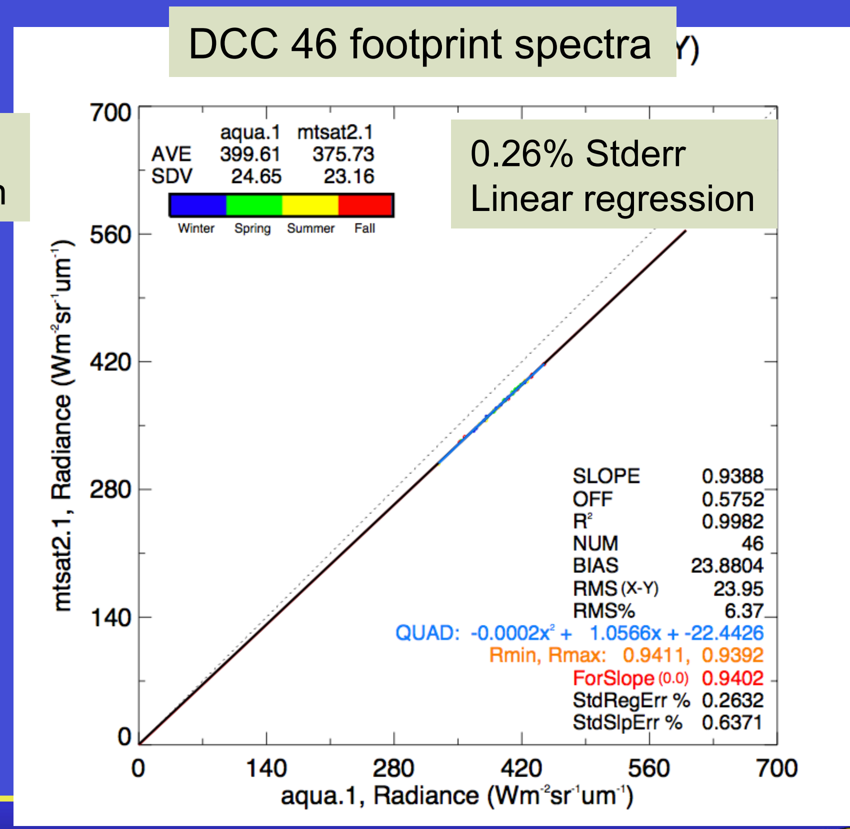


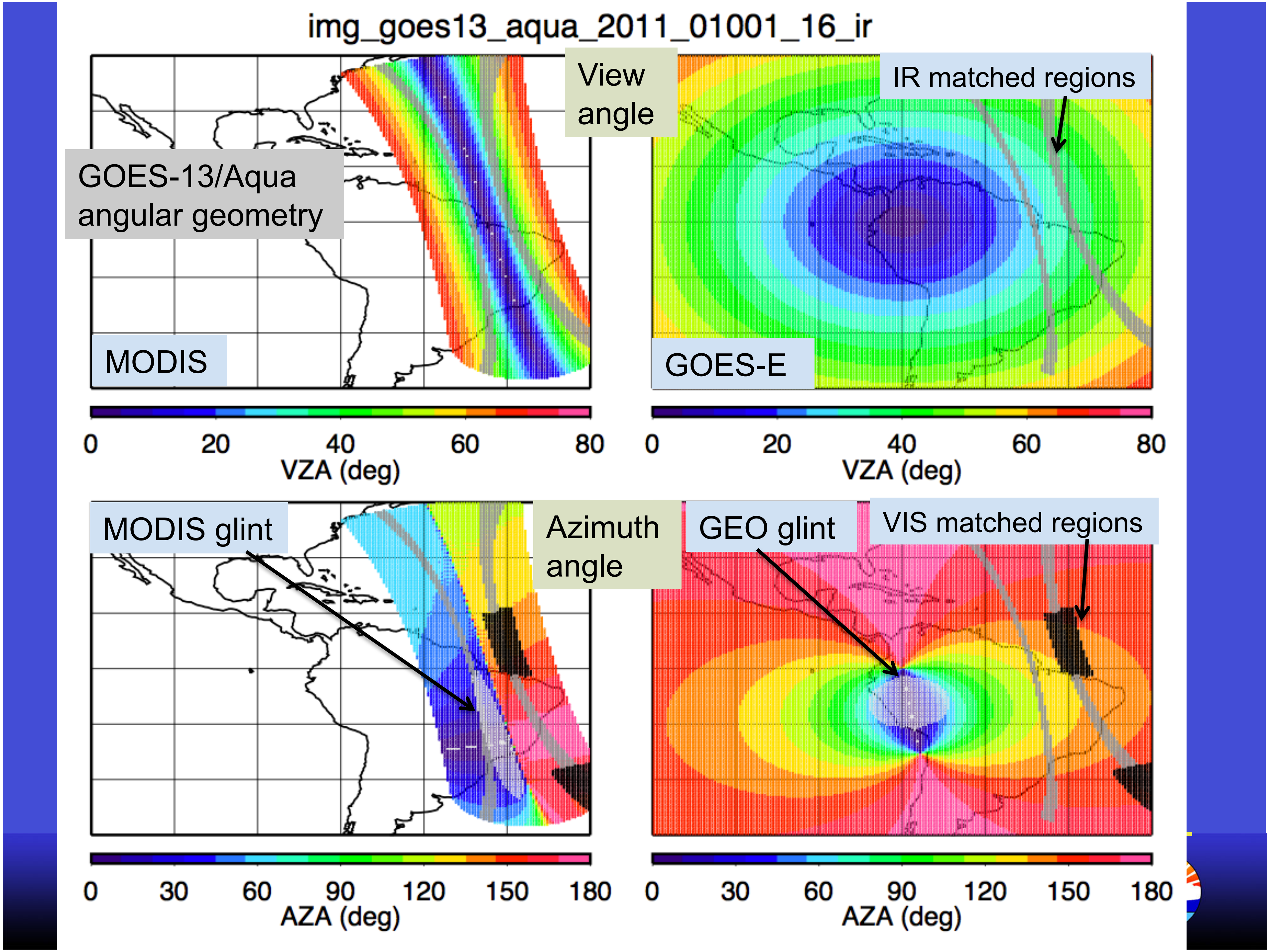


Spectral Band Adjustment Factors (SBAF)

- Convolve footprint SCIAMACHY spectra with the visible band SRF to derive pseudo radiances
- Regress pseudo visible band radiance pairs to derive spectral band adjustment factor (SBAF)
- SBAF takes into account both the scene spectra and band solar constant



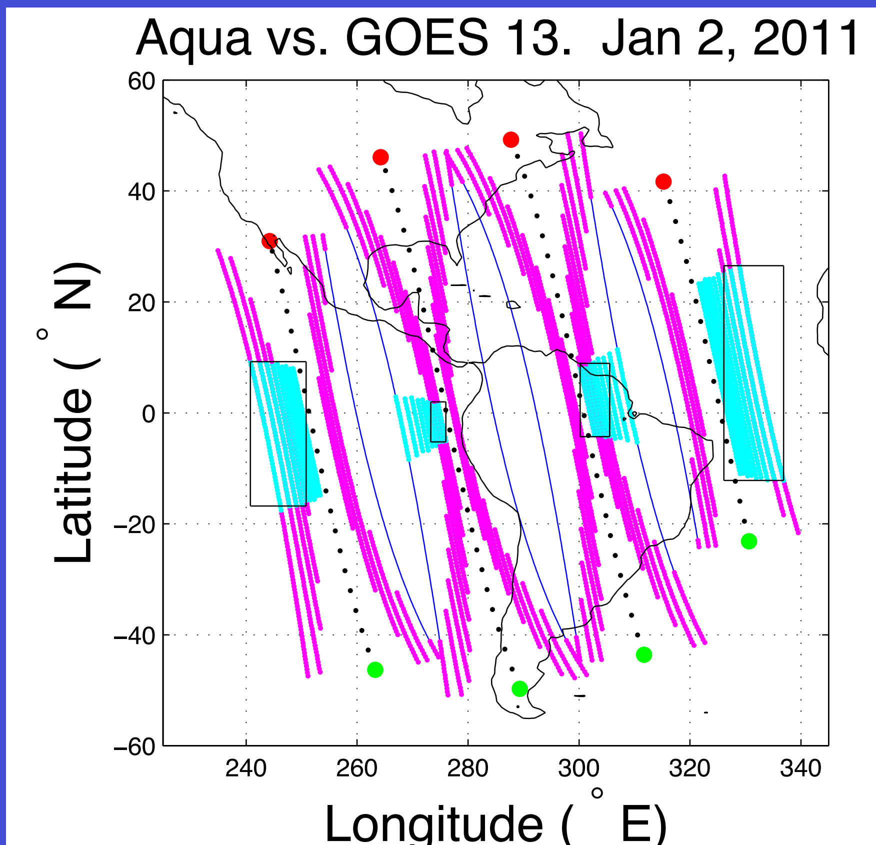




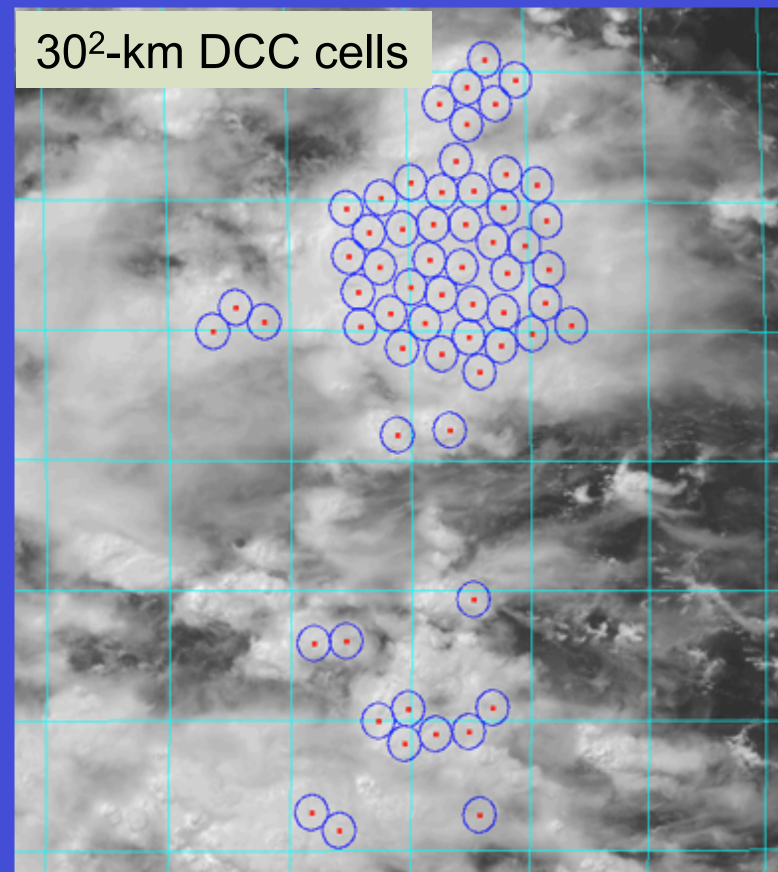
img_goes13_aqua_2011_01001_16_ir
GOES-13/Aqua angular geometry
View angle
IR matched regions
MODIS
GOES-E
0 20 40 60 80
VZA (deg)
0 20 40 60 80
VZA (deg)
MODIS glint
Azimuth angle
GEO glint
VIS matched regions
0 30 60 90 120 150 180
AZA (deg)
0 30 60 90 120 150 180
AZA (deg)

Is there sufficient DCC ray-matched samples?

- Find Aqua-MODIS DCC 30^2 km cells by using pixels with temperature (11µm) 205°K
- Predict GEO angles and if ray-matched find within 15 minute corresponding 1-km GEO visible image
- Ensure no overlapping cells, by locating coldest cells first, and then locating surrounding cells



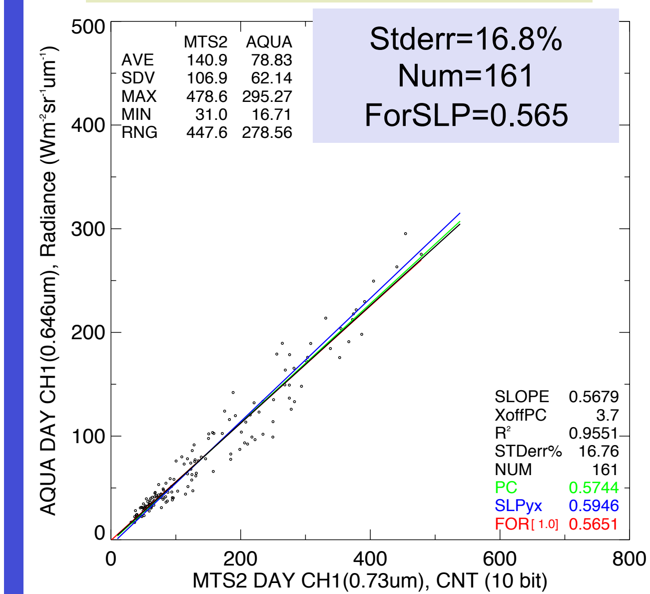
Cyan areas indicate the ray-matched regions, Aqua orbits ~1.5 hours apart



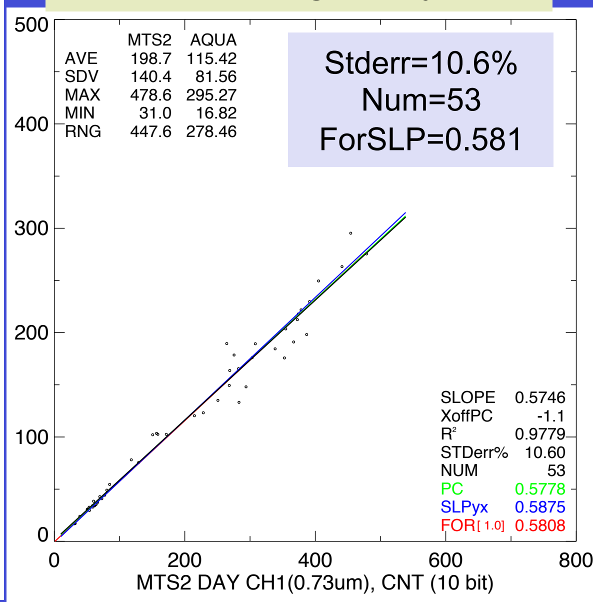
1° lat/lon grid, MTSAT-2, July 20, 2011 2:32 GMT

MTSAT-2/Aqua-MODIS March 2012 radiance pair scatter plot

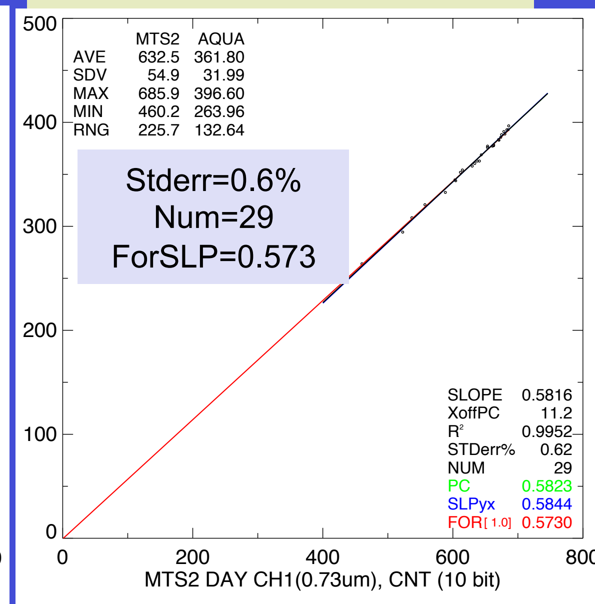
Gridded ray-match



Gridded ray-match and spatial homogeneity filter

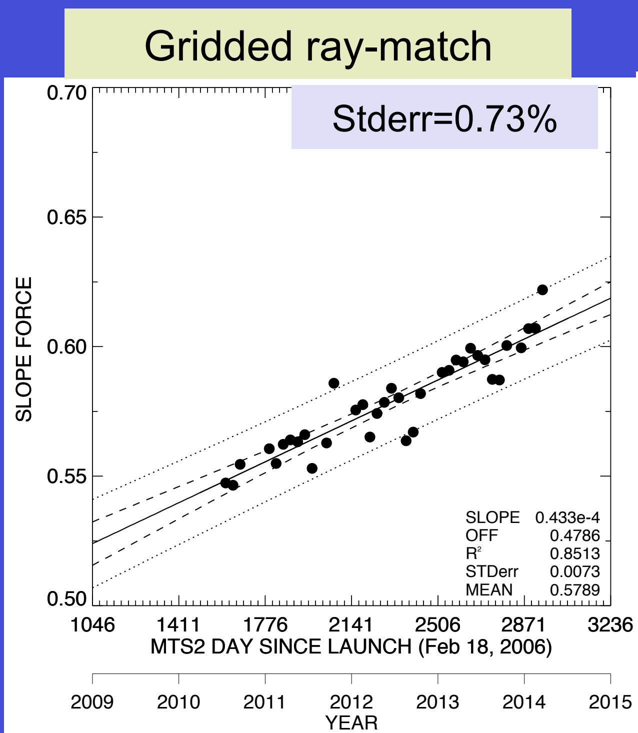


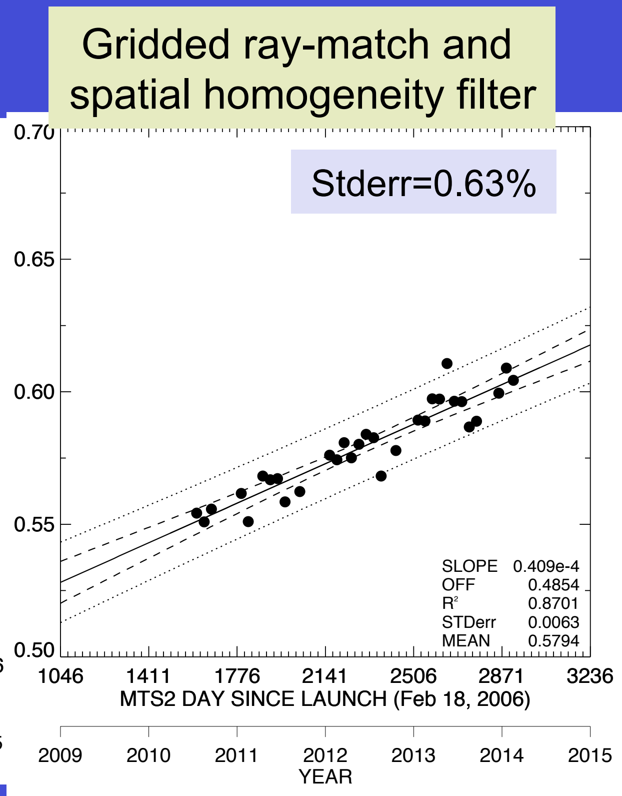
DCC cells and spatial homogeneity filter

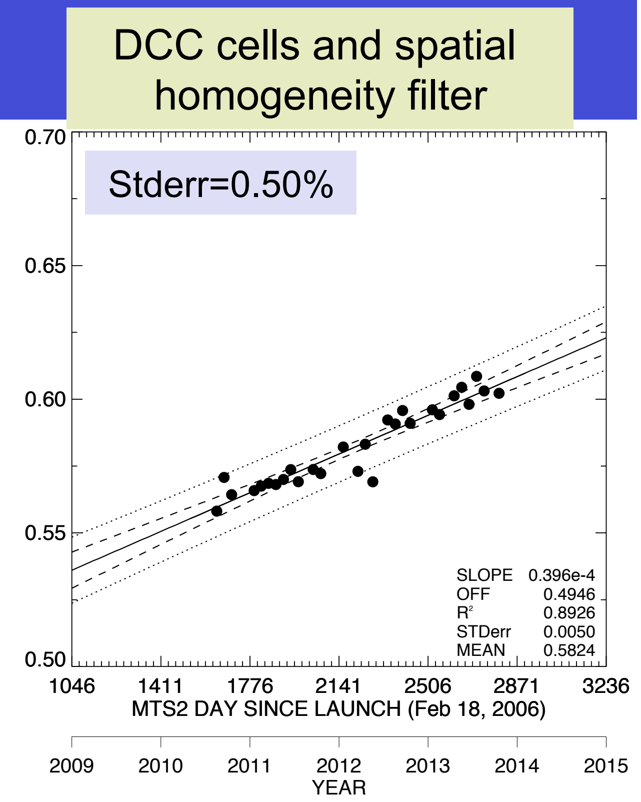


- DCC offers the greatest dynamic range or greatest signal to noise ratio
- It is amazing that DCC slope (black line) and slope through the space count (red line) are within 1.5%
- Sampling will be the disadvantage of the DCC ray-matching method

MTSAT-2/Aqua-MODIS March 2012



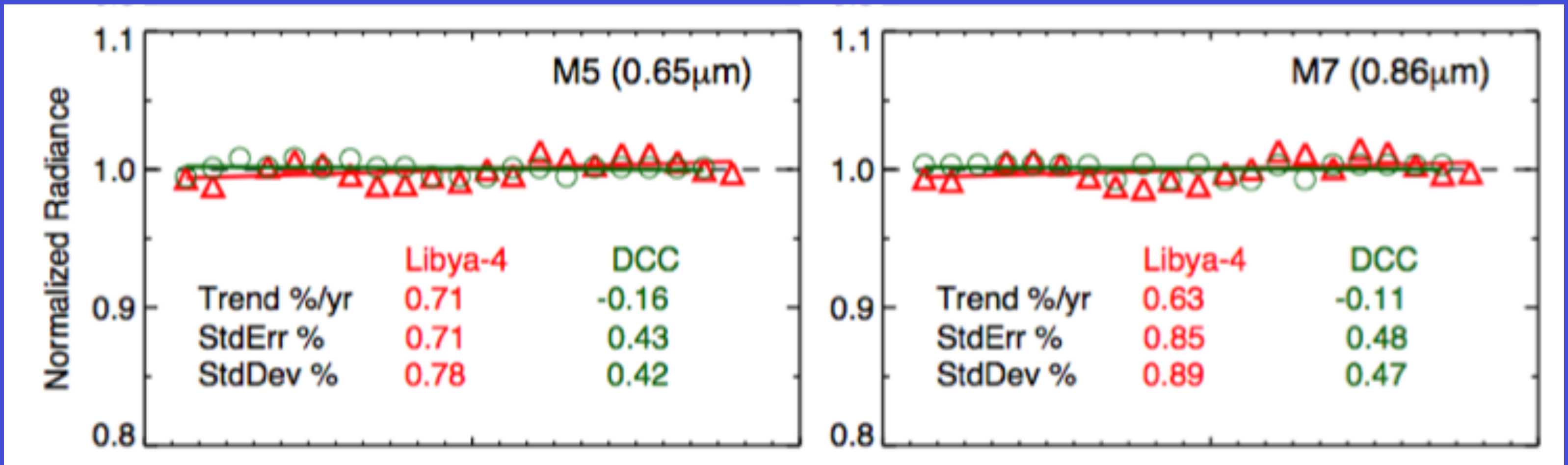




- Looking into DCC monthly outliers to identify sampling or other issues
- Try raising the DCC temperature threshold to 220°K to increase sampling
- Gridded and DCC ray-match absolute calibration within 0.5%, and trend within 0.04%/year

NPP-VIIRS stability

• CERES uses the NPP-VIIRS Land-PEATE product calibration based on VCST (Jack Xiong) and is recalibrated over the record based on Collection 1.1
• The NOAA-CLASS archived NPP-VIIRS is based on the NOAA official calibration and the calibration is updated only over time not reprocessed over the record
• VIIRS NIR bands (0.86µm) onboard sensitivity degraded over 30% in 2-years and is accounted for in the calibration
• Use DCC and Libya-4 pseudo invariant sites to determine the stability of the land-PEATE calibrated VIIRS radiances



• The DCC and Libya-4 trends are of opposite sign, however using the Weatherhead 1998 significance test, which takes into account record length, monthly variability, and autocorrelation, the trends are not significant
• VIIRS trends are within 0.75%/year, Aqua-MODIS trends are within ~1%/decade

NPP-VIIRS stability (trend standard errors %)

VIIRS Band	Libya-4			DCC		
	Observed MODIS stability		Observed VIIRS stability	Observed MODIS stability		Observed VIIRS stability
	Full record	VIIRS timeframe		Full record	VIIRS timeframe	
0.49 µm	1.1	1.3	1.43	0.8	0.5	0.49
0.56µm	1.0	1.2	1.10	0.7	0.5	0.53
0.65µm	0.9	1.0	0.79	0.9	0.6	0.42
0.86µm	1.0	1.0	0.89	MODIS band saturates		0.47
1.61µm	0.8	0.9	1.10	2.1	2.1	2.21
2.25µm	1.9	2.1	1.56	3.9	3.1	1.58
I 0.64µm	0.9	1.0	0.83	0.9	0.6	0.52
I 1.61µm	0.8	0.9	1.29	2.1	2.1	2.19

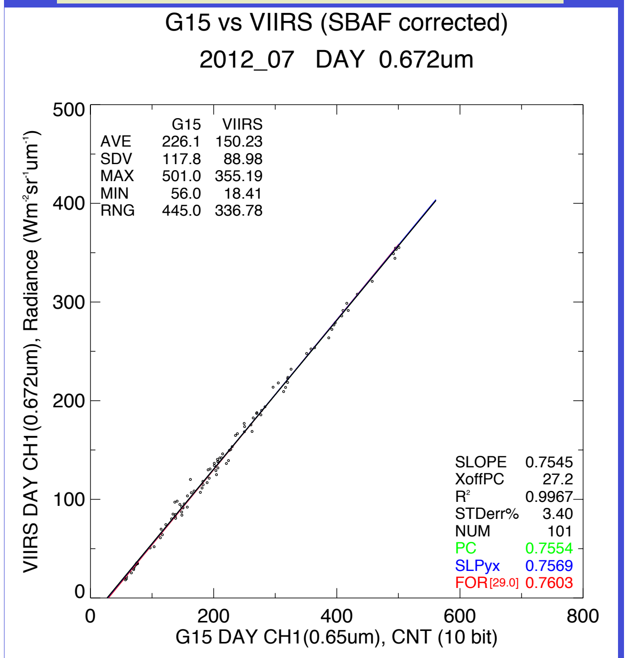
- NPP-VIIRS 0.65µm temporal noise seems to be less than Aqua-MODIS
- It is predicted that DCC can detect a NPP-VIIRS 1%/decade trend in 5-years and Libya-4 a 1%/decade trend in 10-years

• Bhatt et al. 2014, Initial Stability Assessment of S-NPP VIIRS Reflective Solar Band Calibration Using Invariant Desert and Deep Convective Cloud Targets, *Remote Sens.* **2014**, *6*(4), 2809-2826

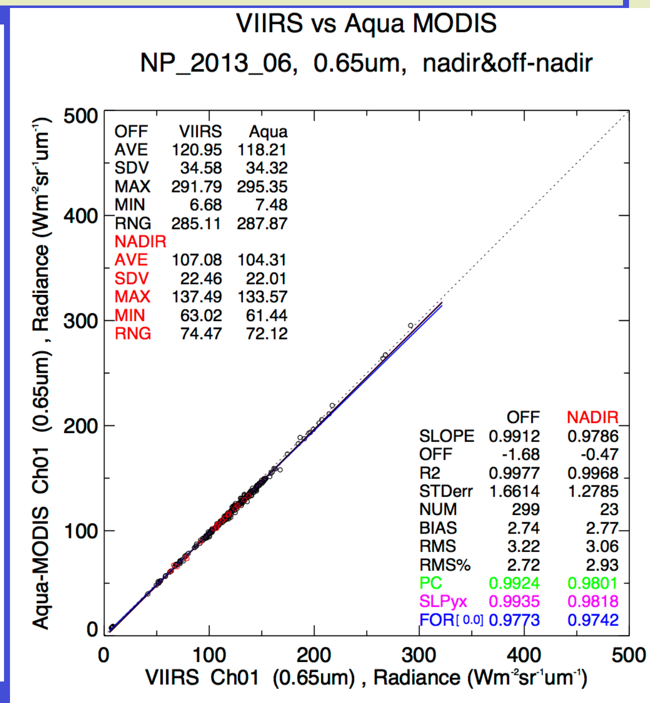
NPP-VIIRS as calibration reference

(VIIRS is future calibration reference for GEO)

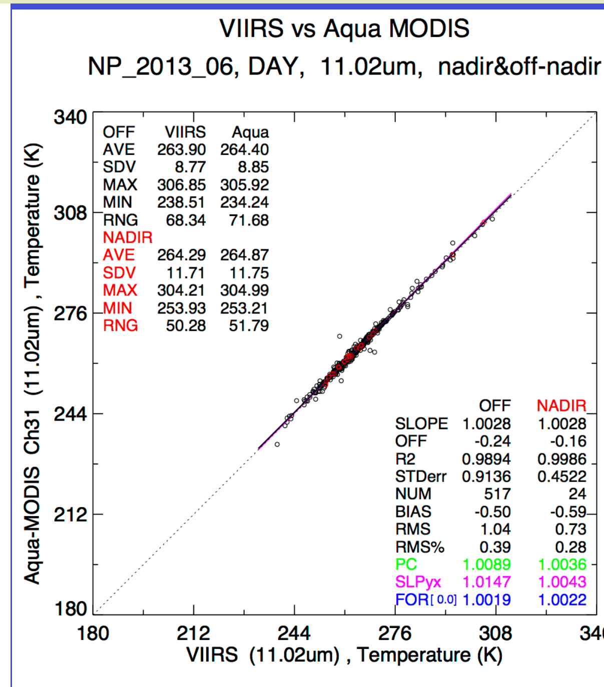
GOES-15/NPP-VIIRS 0.65µm, July 2012



Aqua-MODIS/NPP-VIIRS SNO, 0.65µm, June 2013



Aqua-MODIS/NPP-VIIRS SNO, 11µm, June 2013



- Currently using Aqua-MODIS as GEO calibration reference
- Demonstrated using NPP-VIIRS instead of Aqua-MODIS as GEO calibration reference
- Continue to finalize the GEO/VIIRS and MODIS/VIIRS codes
- Able to tie the Aqua-MODIS and NPP-VIIRS calibration references, already have tied the Terra and Aqua-MODIS calibration

GEO LW NB to BB flux approaches

Ed2

NB Radiance to BB flux
Bins
Surface Type (2)

For each bin (based on GEO/CERES)

$$LW_{BB} = a_0 + a_1 LW_{wn} + a_2 LW^2{}_{wn}\, a_2 ln(colRH)$$
$$LW_{wn} = (2\pi Rad_{wn})/(l_0 + l_1 ln(cos(VZA)))$$

1-step

NB Radiance to BB flux
Bins
Surface Type (7)
VZA (7)
WN Rad (7)

For each bin (based on SSF)

$$Rad_{BB} = a_0 + a_1 Rad_{wn} + a_2 Rad_{wv}$$

2-step

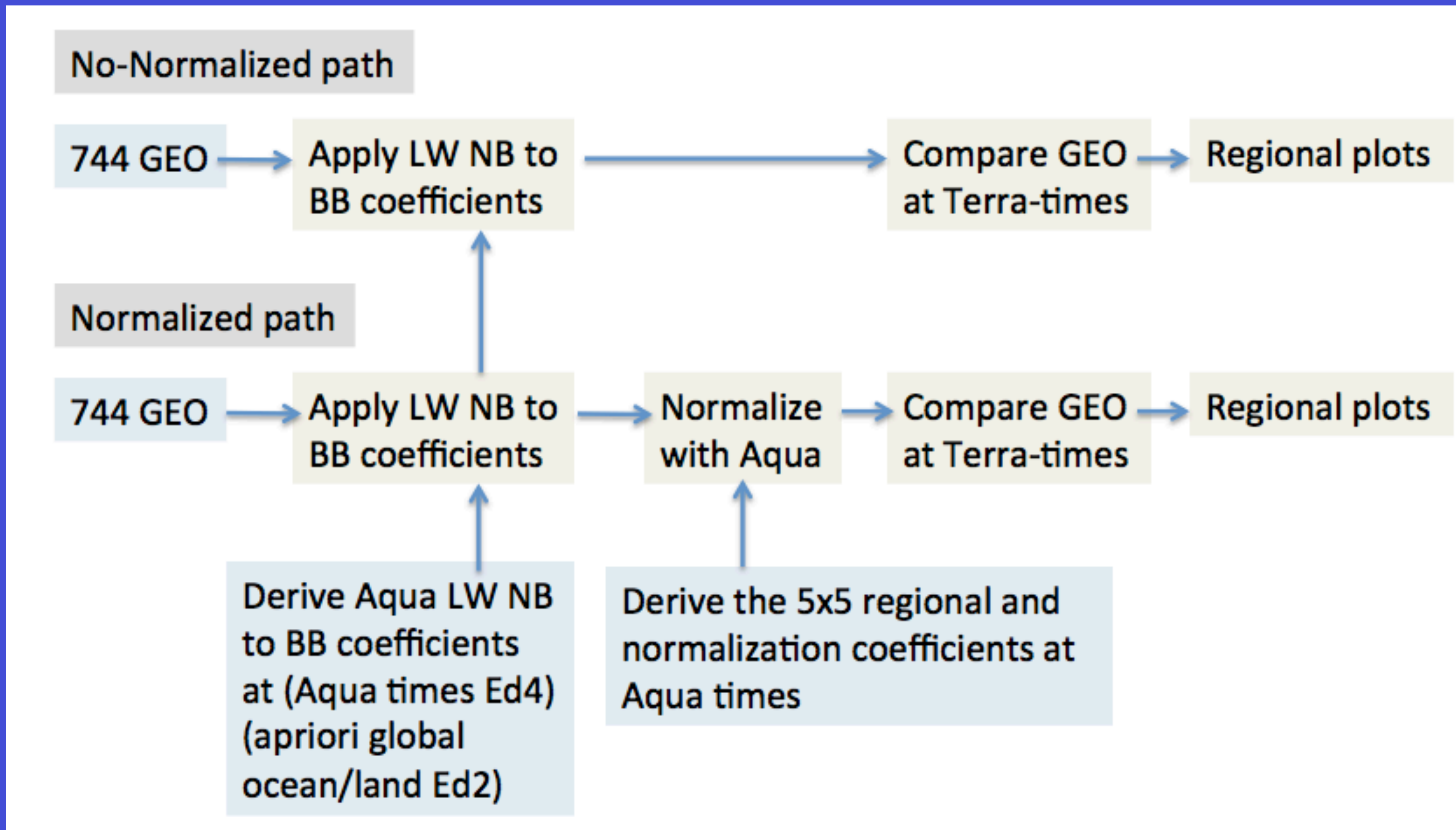
NB to BB radiance
Bins similar to CERES ADM
Surface Type (7)
VZA (7)
Cloud/Clear (6)
PW (3)
Lapse Rate (6)
IR emissivity (6)

For each bin (based on SSF)

$$Rad_{BB} = a_0 + a_1 Rad_{wn} + a_2 Rad_{wv}$$

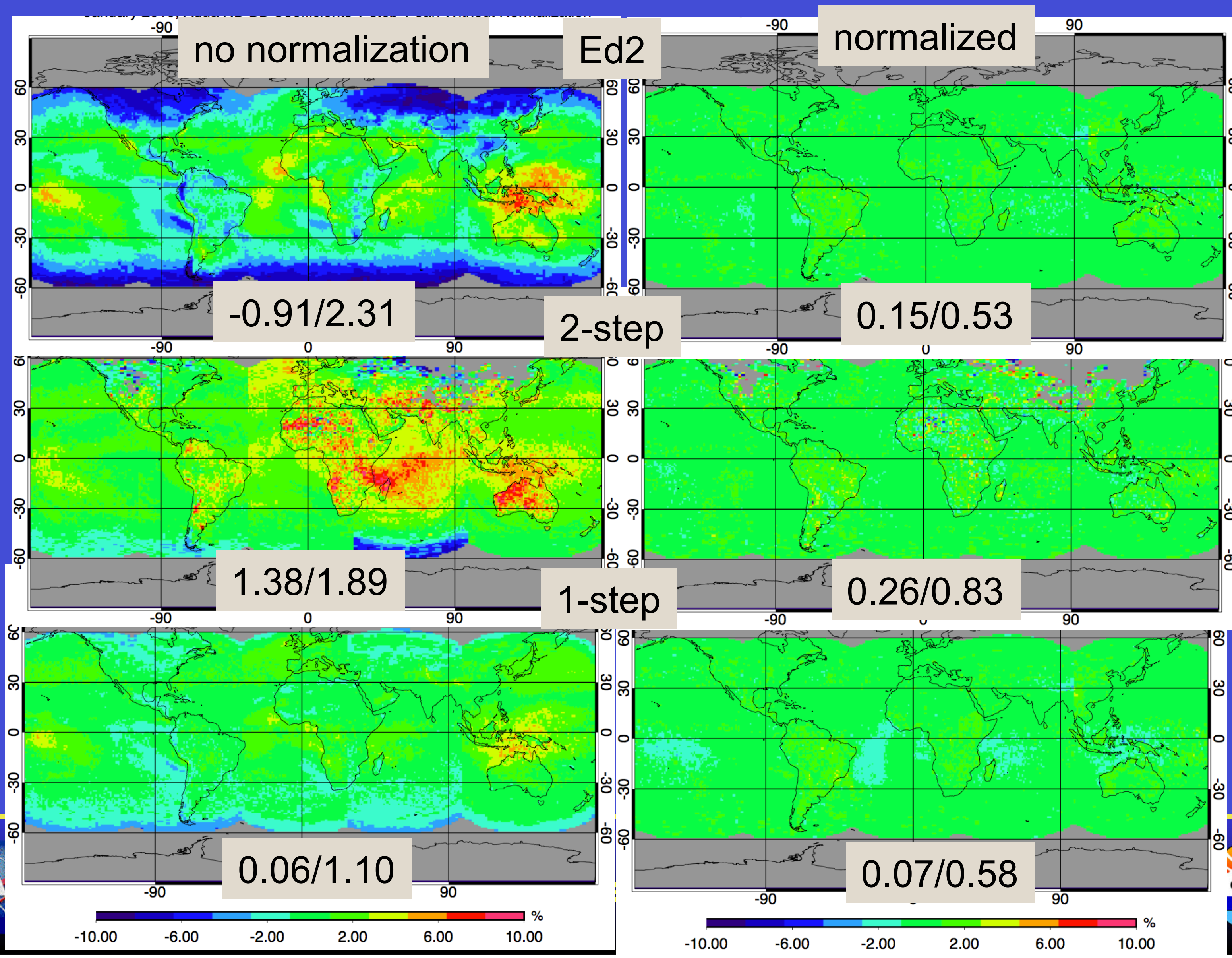
BB radiance to flux
CERES ADM

LW NB to BB approach validation

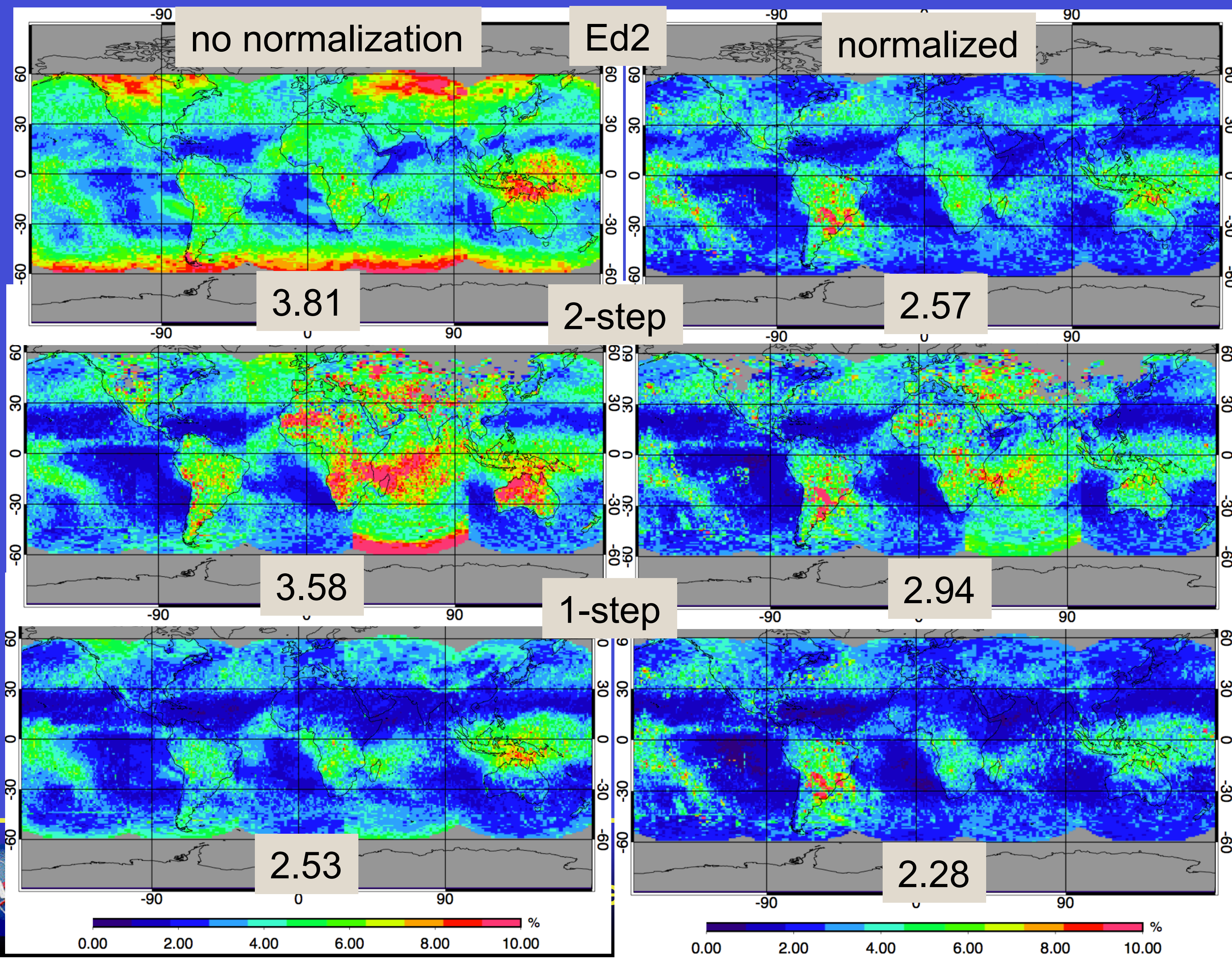


- Previous CERES STM showed the LW NB to BB validation with respect to GERB
- Eventually also use Megha-tropiques ScaRaB to validate the GEO LW NB to BB fluxes
- Compute the regional GEO – CERES LW flux bias and RMS error at Terra times

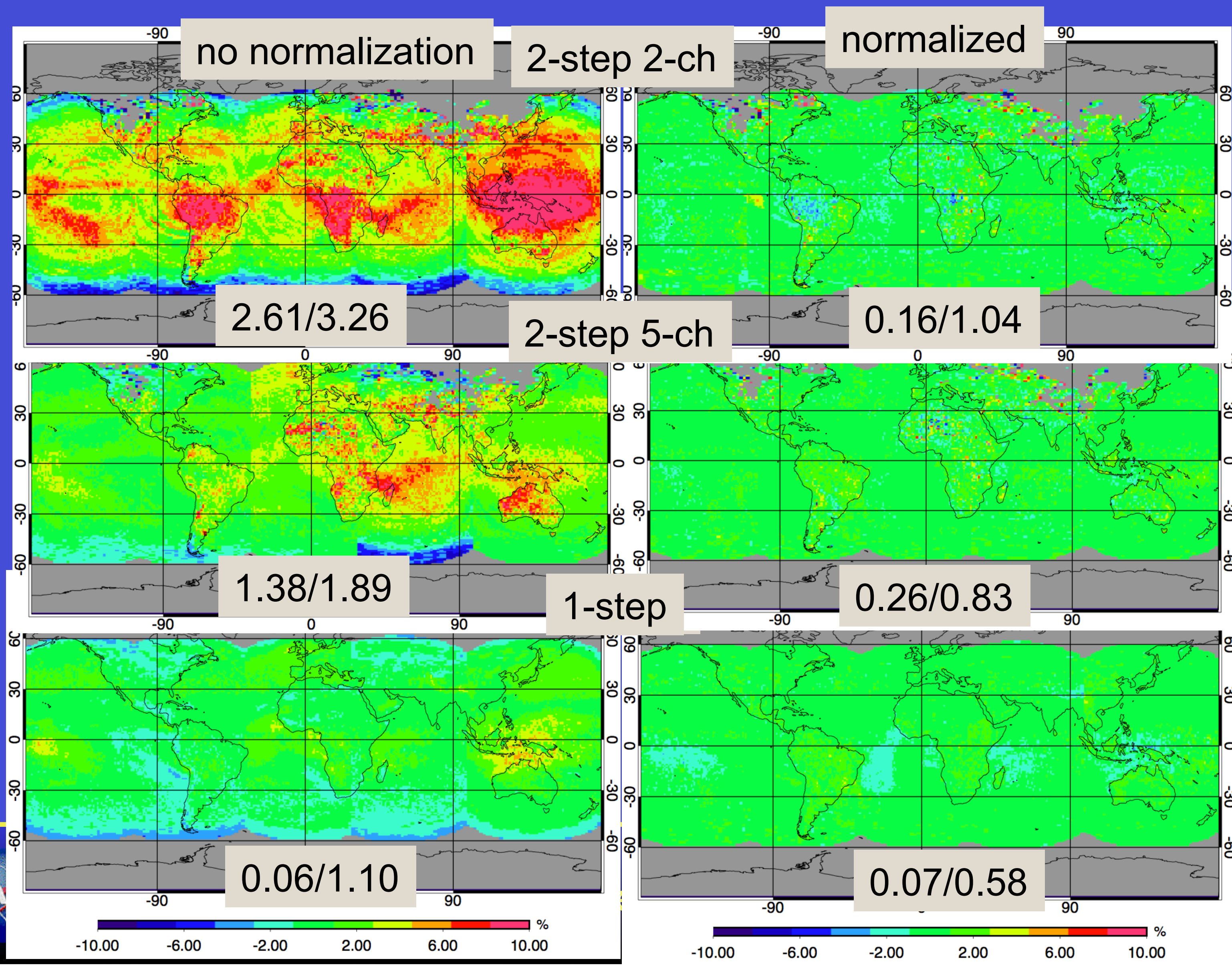
Bias impact of LW NB to BB approaches



RMS error impact of LW NB to BB approaches



Bias impact of cloud quality on 2-step approach



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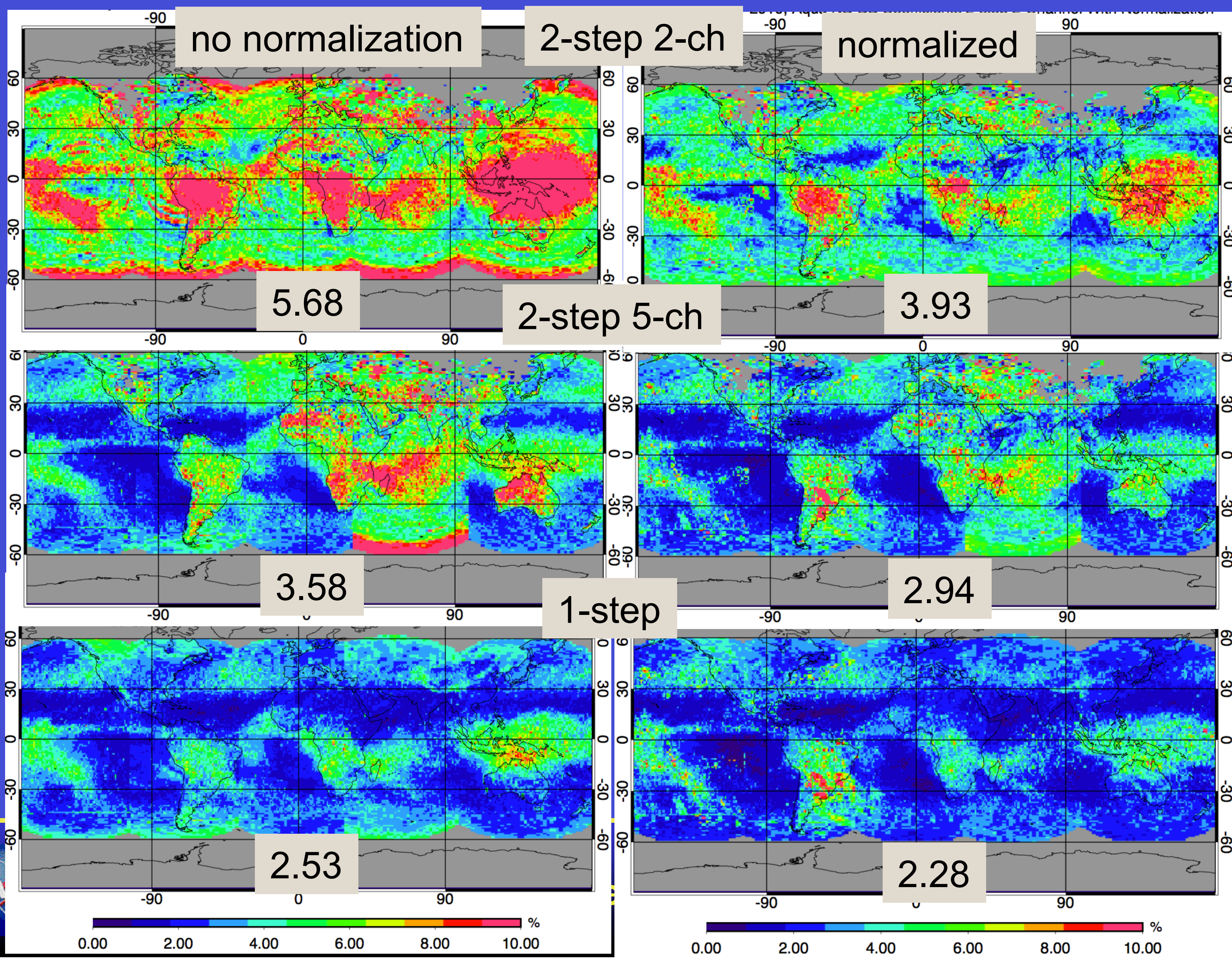
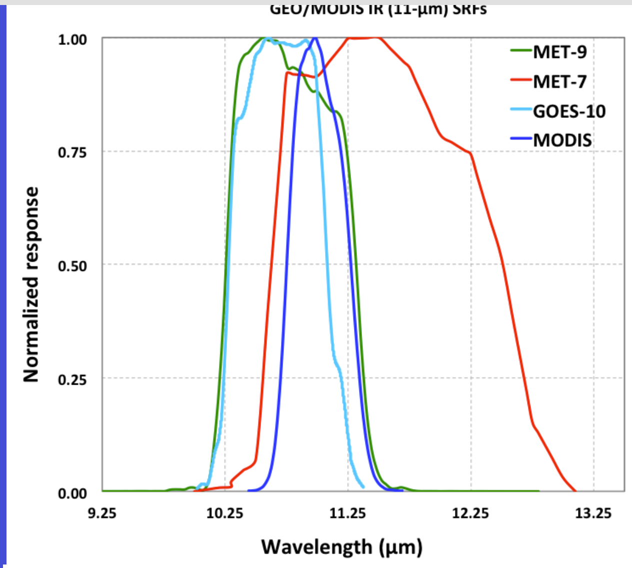
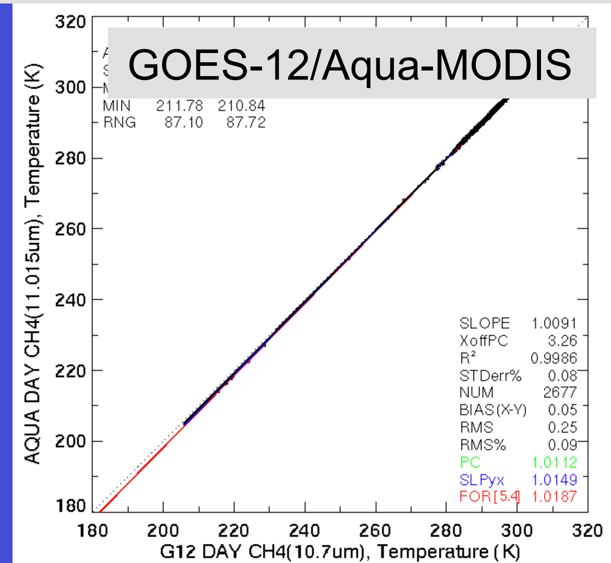


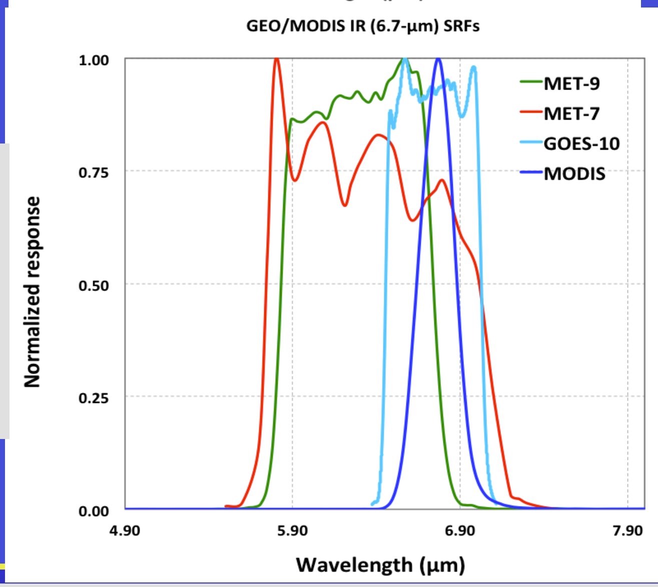
Adjust the GEO radiance to match MODIS spectral response

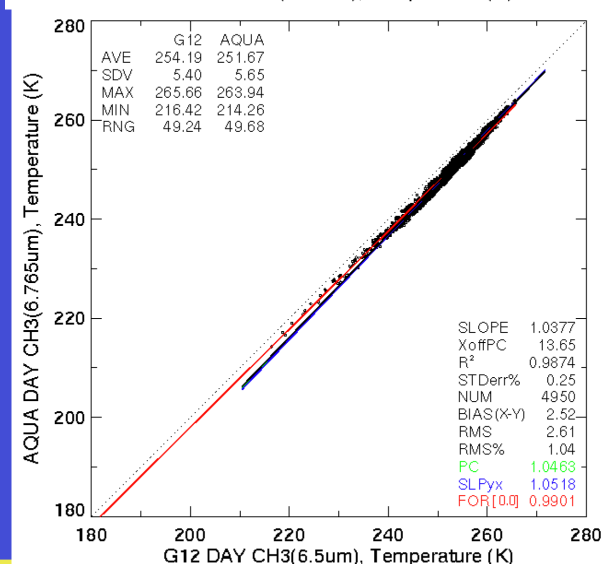
WN (11µm)





WV (6.5µm)





- The LW NB to BB coefficients were obtained using MODIS radiance and CERES fluxes

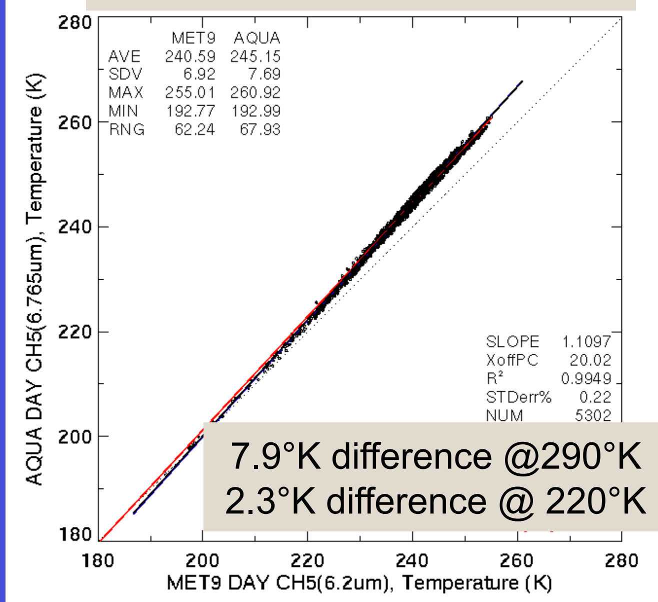
- Terra-MODIS WV channel has electronic cross-talk issues can only adjust with Aqua-MODIS

- Perform monthly regressions of coincident temperature pairs during both day and night
- Regress the slope and offset temporally over the lifetime of GEO record

GEO WV SBAF

(spectral band adjustment factor)

Met-9/Aqua-MODIS WV June 2012



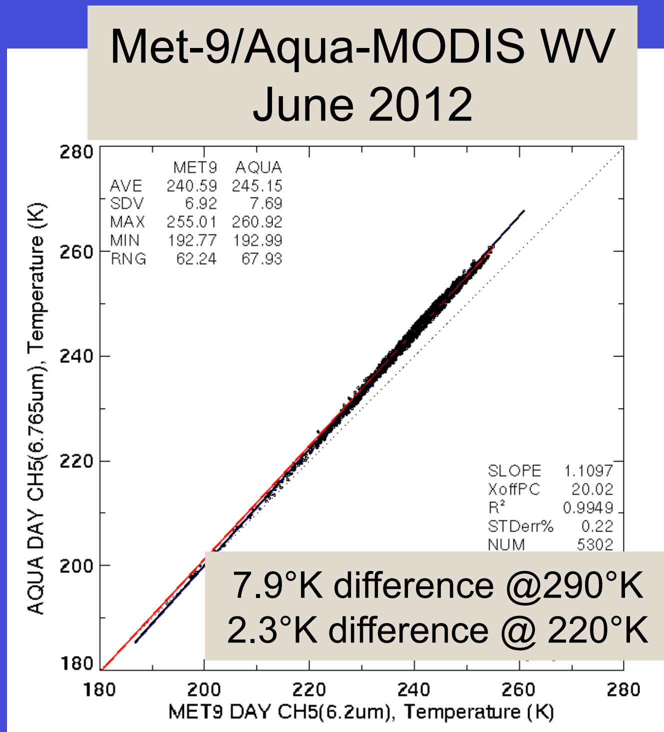
GEO-MODIS WV temperature difference @ 290°K

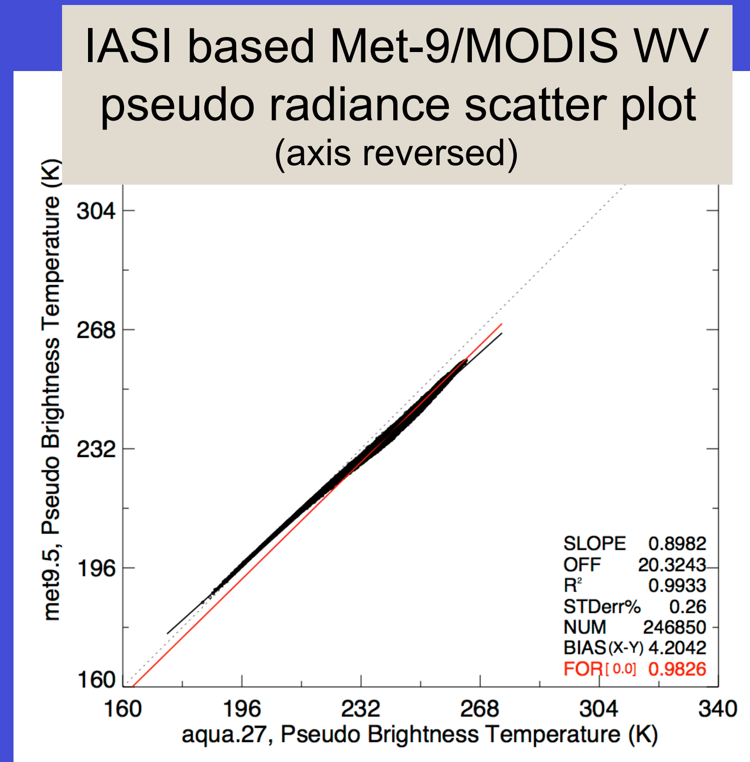
(290°K is an unrealistic WV temperature, was chosen to consistent with 11µm

GEO @290°K	Aqua-Night	Aqua-Day	IASI GSICS-day	IASI GSICS-night
GOES-13	-2.09	-3.32	0.36	0.34
GOES-14	-2.63	-3.32		
GOES-15	-0.89	-2.23	0.31	0.31
Meteosat-7	-1.48	-1.28	-2.78	-2.80
Meteosat-9	8.10	7.87	0.17	0.18
Meteosat-10	7.78	7.20	0.39	0.39
MTSAT-1R	1.42	0.94		
MTSAT-2	0.79	0.28	0.04	0.05

- SSF derived LW NB to BB coefficients rely on MODIS equivalent GEO IR temperatures
- GSICS GEO IR calibration is based on IASI hyper-spectral and GEO ray-matched radiances and takes into account the spectral band difference
- The GSICS IR calibration is more consistent with MODIS, except Met-7

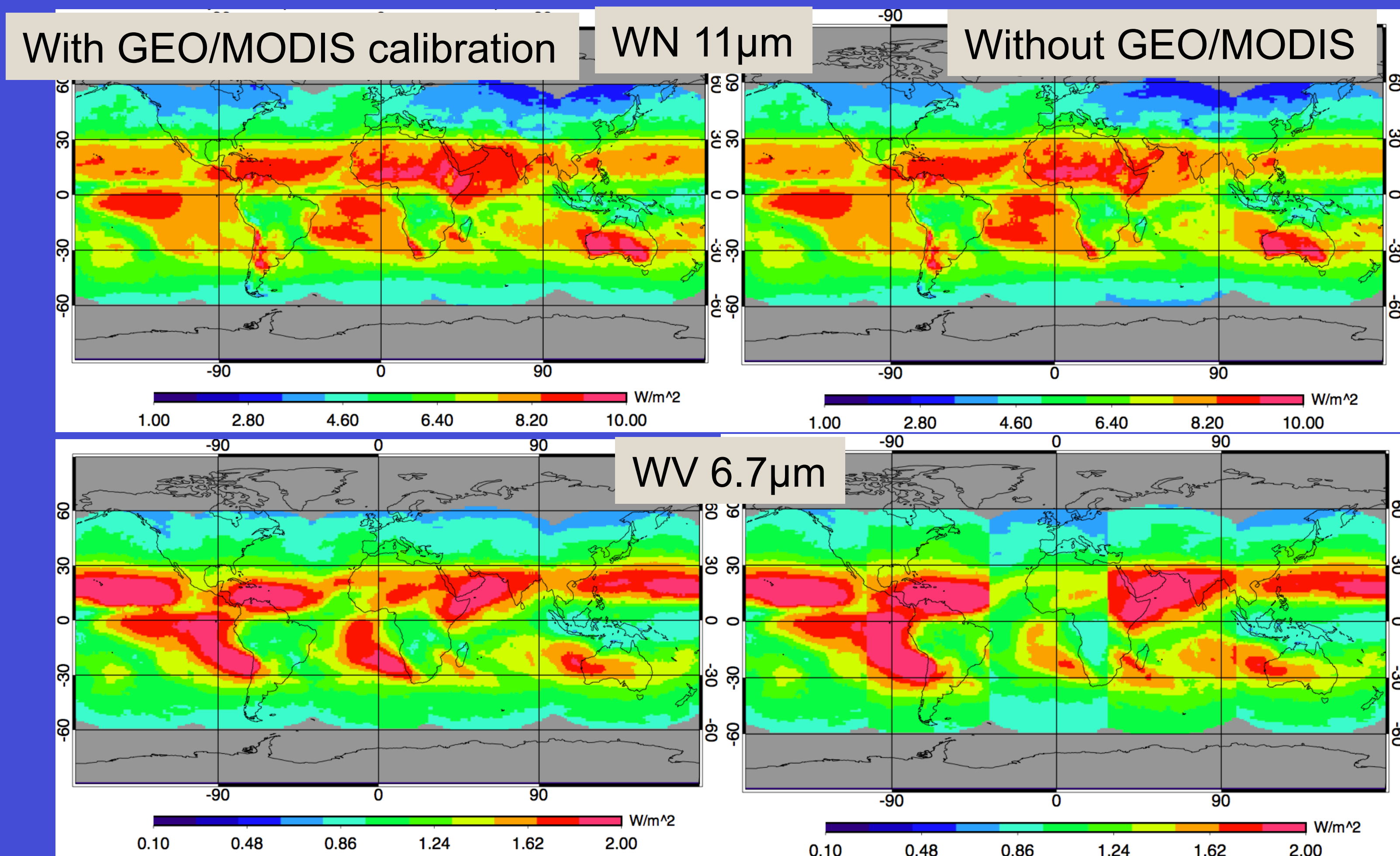
GEO WV IASI SBAF



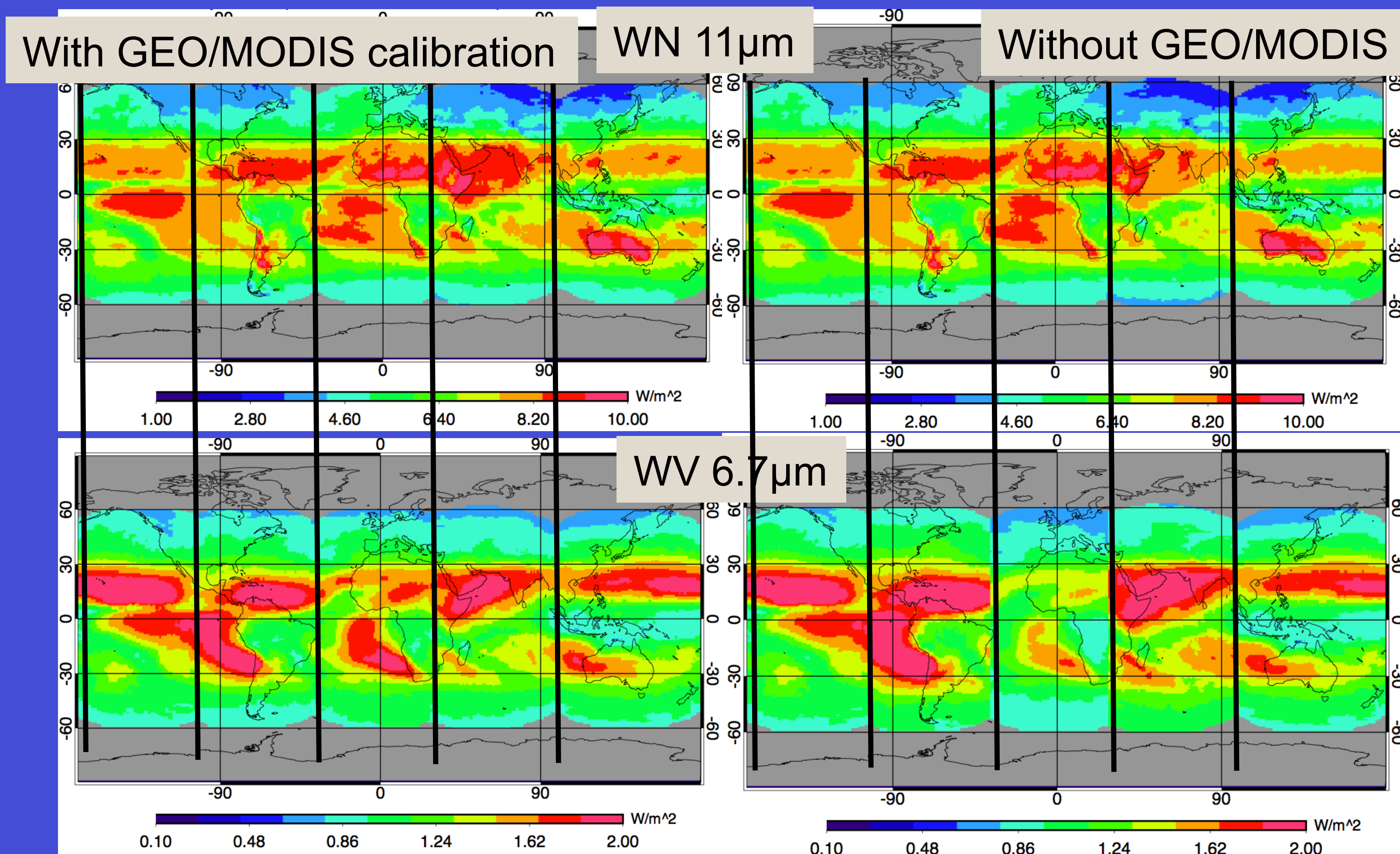


- The IASI based WV pseudo radiances are sufficient to derive the SBAF for MODIS/GEO temperature differences, and therefor derive nearly the true GEO WV temperature similar to the GSICS IASI based GEO reference calibration
- This allows GSICS equivelant IR calibration of pre-IASI GEO imagers
- This approach is similar to the SCIAMACHY based MODIS/GEO visible SBAF

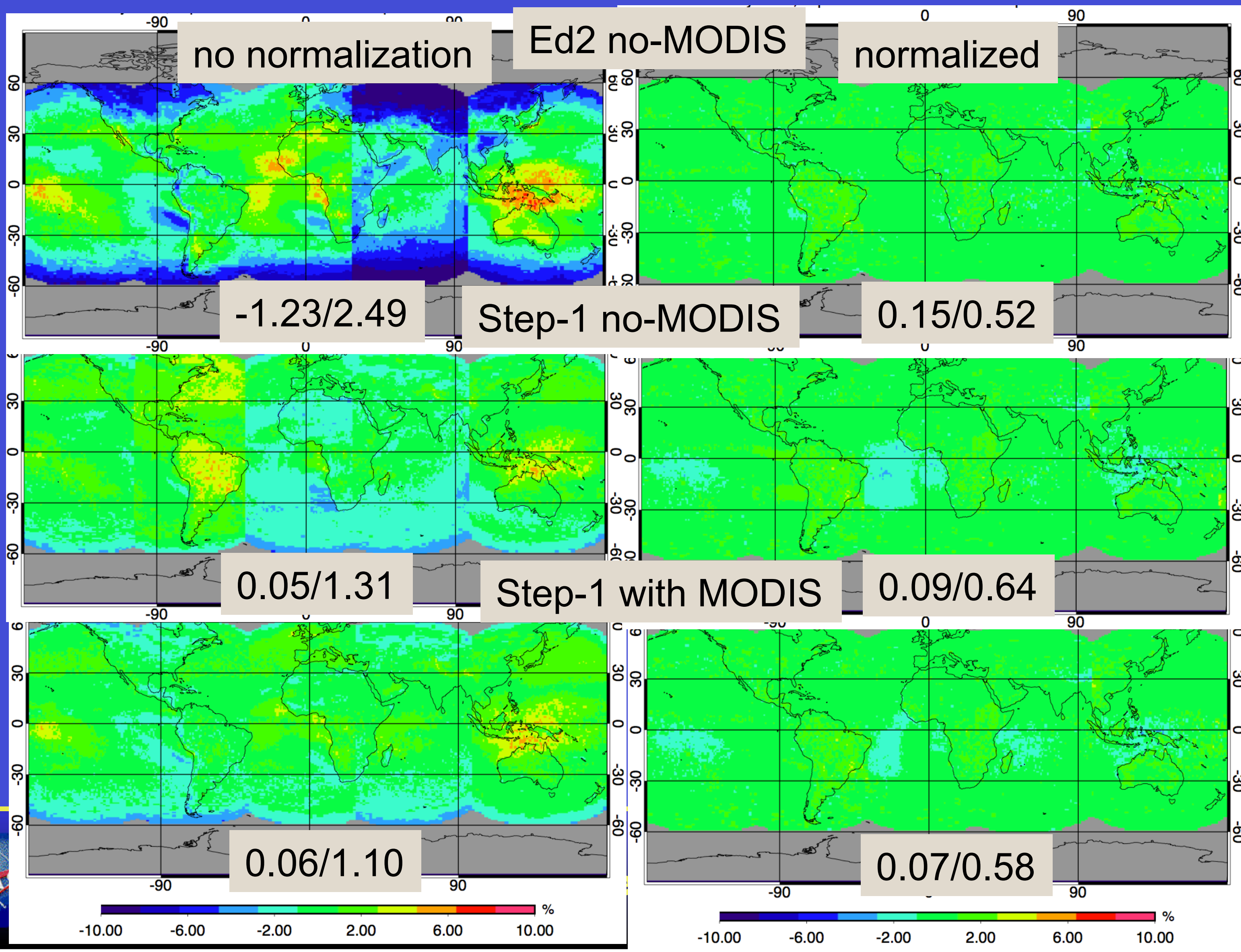
WN and WV GEO composite radiances



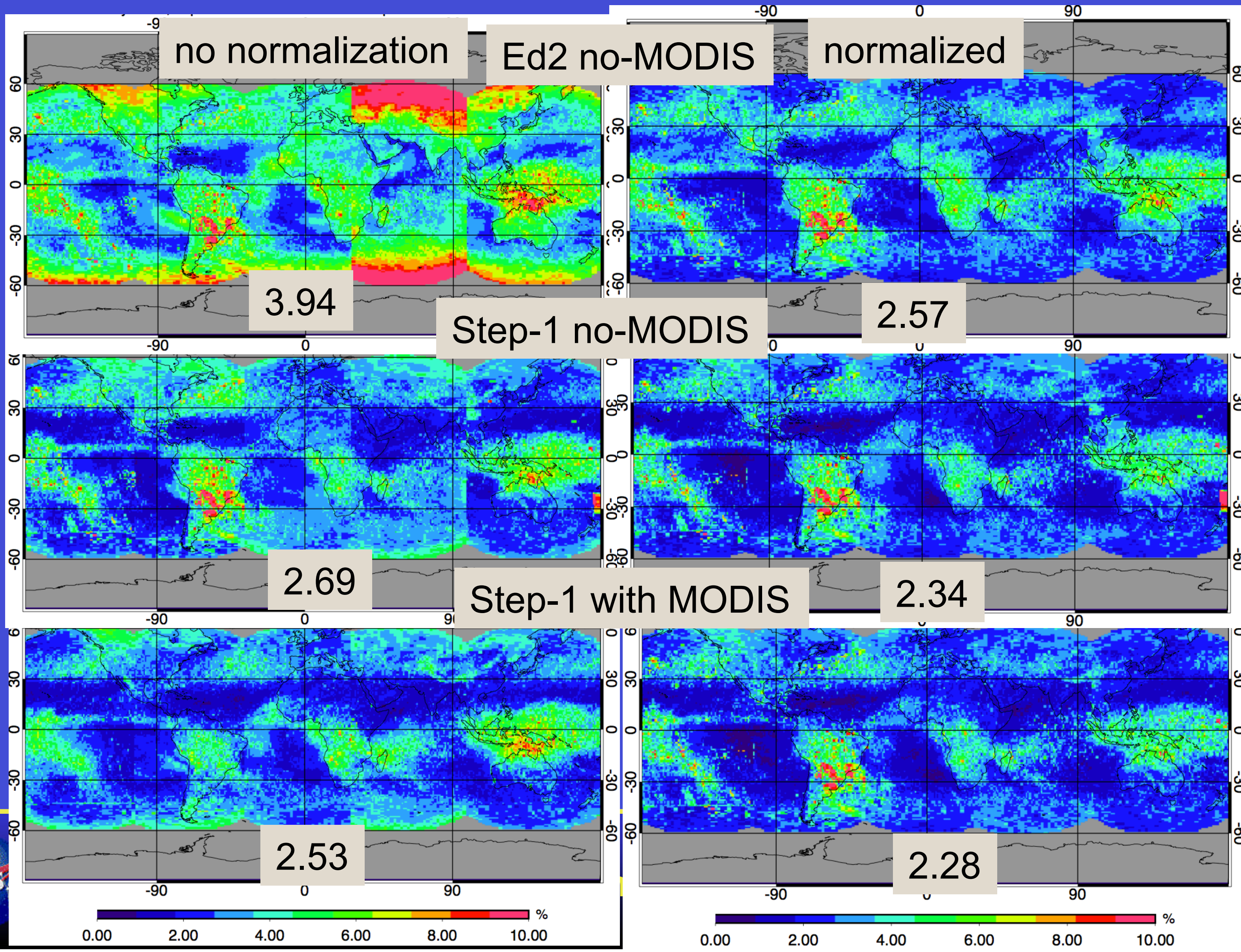
WN and WV GEO composite radiances



Bias Impact of GEO/MODIS IR calibration

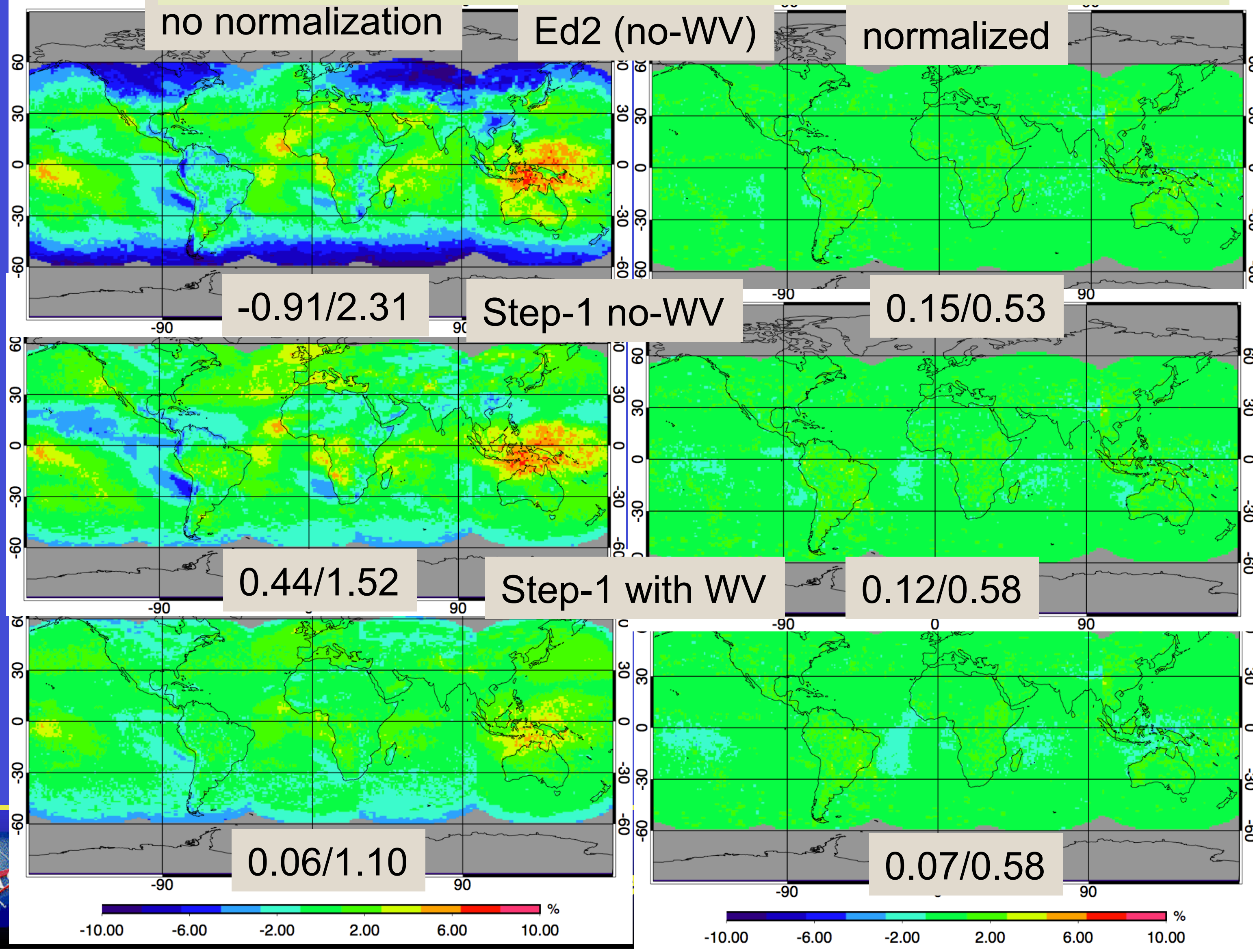


RMS error impact of GEO/MODIS IR calibration



Bias impact of no WV on 1-step

- 1-step WN-only an improvement over Ed2 WN-only with ColRH



RMS error impact of no WV on 1-step

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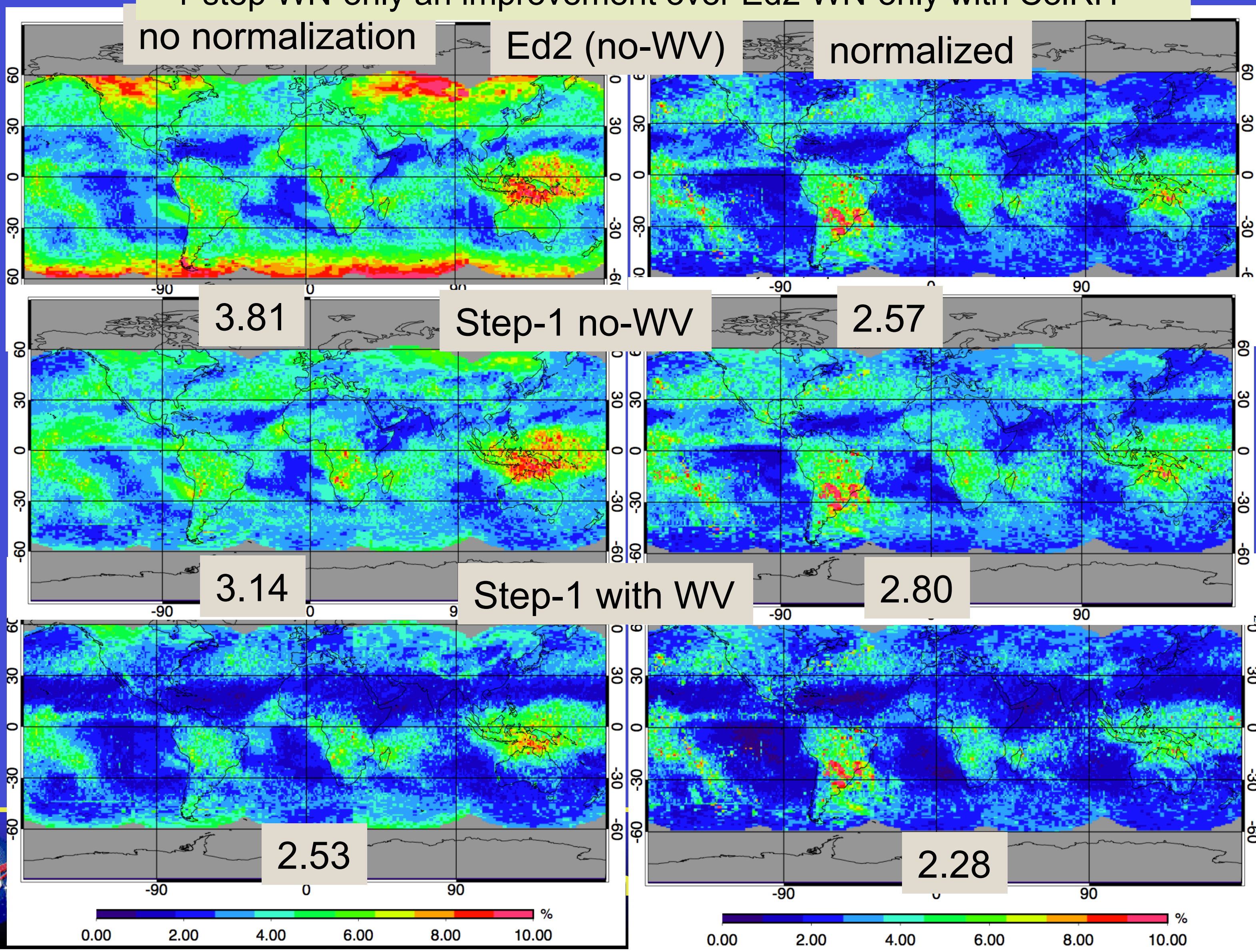


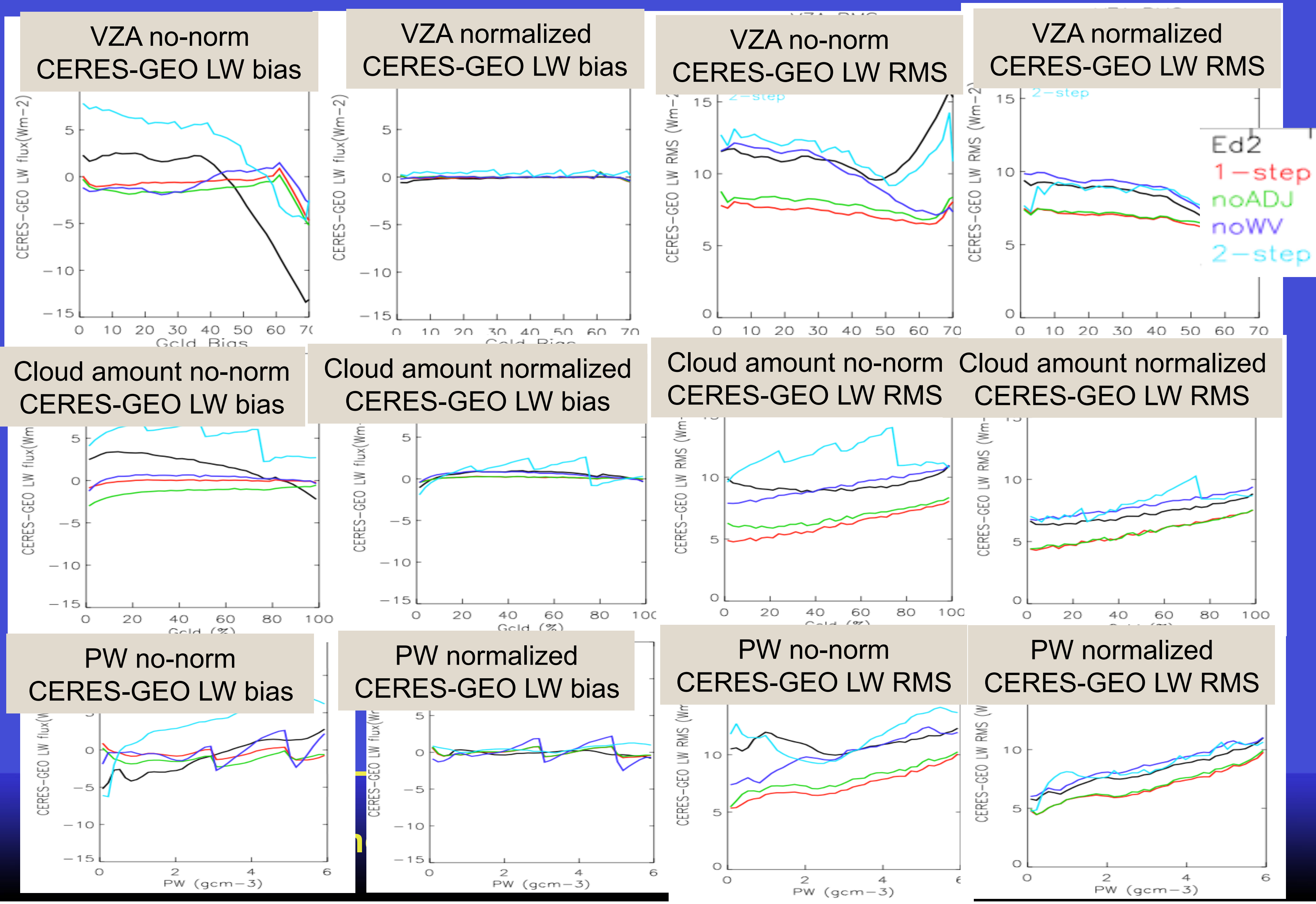
Jan 2010, GEO-CERES LW NB to BB bias and RMS errors (%)

* Regional bias standard deviation

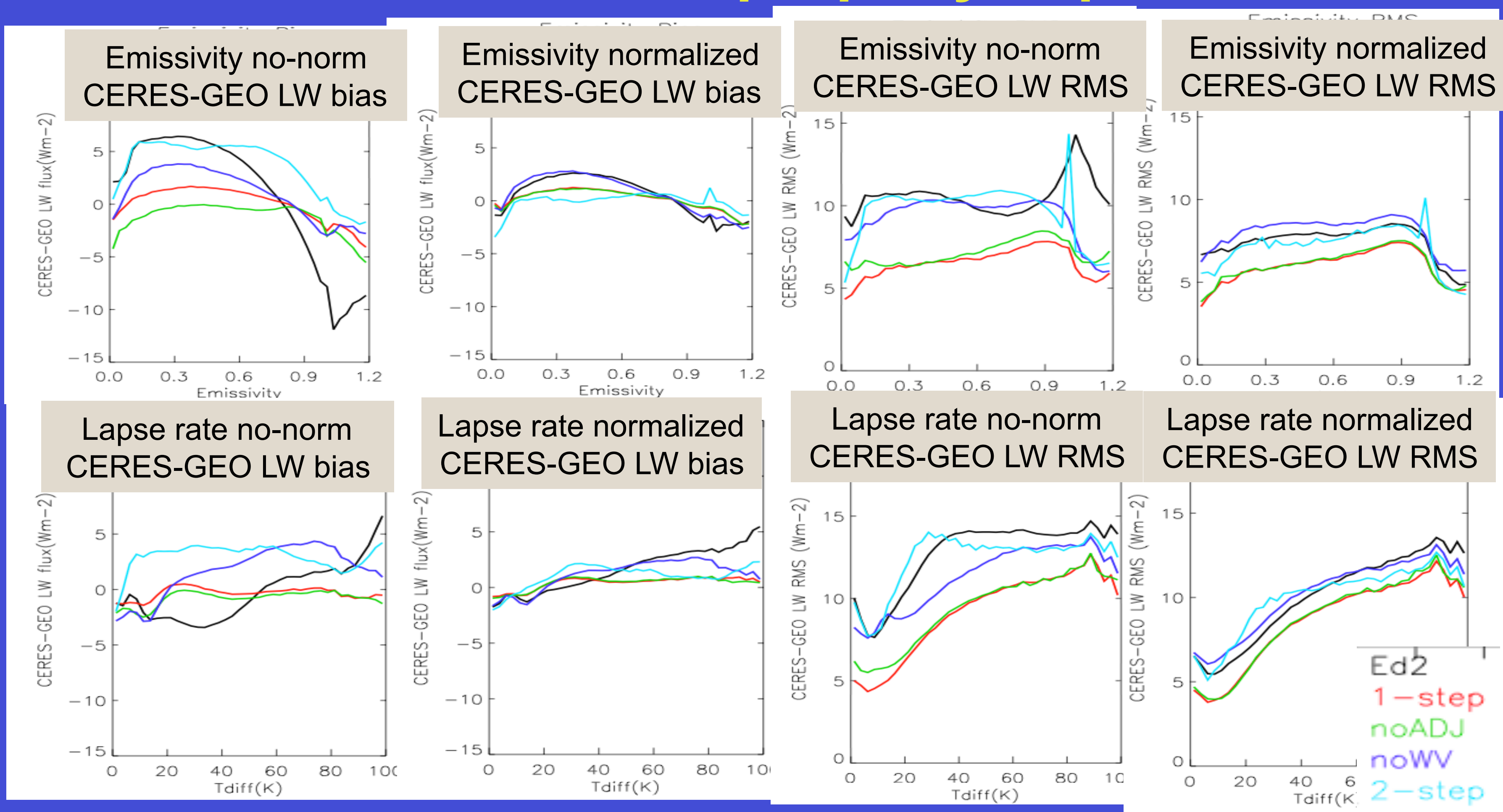
LW NB to BB method	No-norm Bias/*	Normalized Bias/*	No-norm RMS error	Normalized RMS error
Ed2	-0.74/2.39	0.15/0.52	3.83	2.57
1-step	0.24/1.17	0.08/0.58	2.62	2.28
1-step no MODIS	0.05/1.31	0.09/0.64	2.70	2.34
1-step no WV	0.60/1.66	0.12/0.59	3.25	2.81
2-step 5-ch	1.38/1.89	0.08/0.58	3.57	2.94
2-step 2-ch	2.61/3.26	0.16/1.05	5.68	3.93
Ed2 3-hourly	-0.66/2.81	0.02/1.24	5.55	4.46
1-step 3-hourly	0.43/1.46	0.11/0.80	3.48	3.19

- Normalization removes the overall domain bias for all methods
- 1-step has the lowest overall regional bias
- 1-step has a 30% RMS improvement using 1-hourly GEO, 20% RMS improvement using WV channel
- 2-step relies on MODIS-like clouds, GEO 2-channel clouds are different than MODIS

LW NB to BB cloud property dependencies



LW NB to BB cloud property dependencies



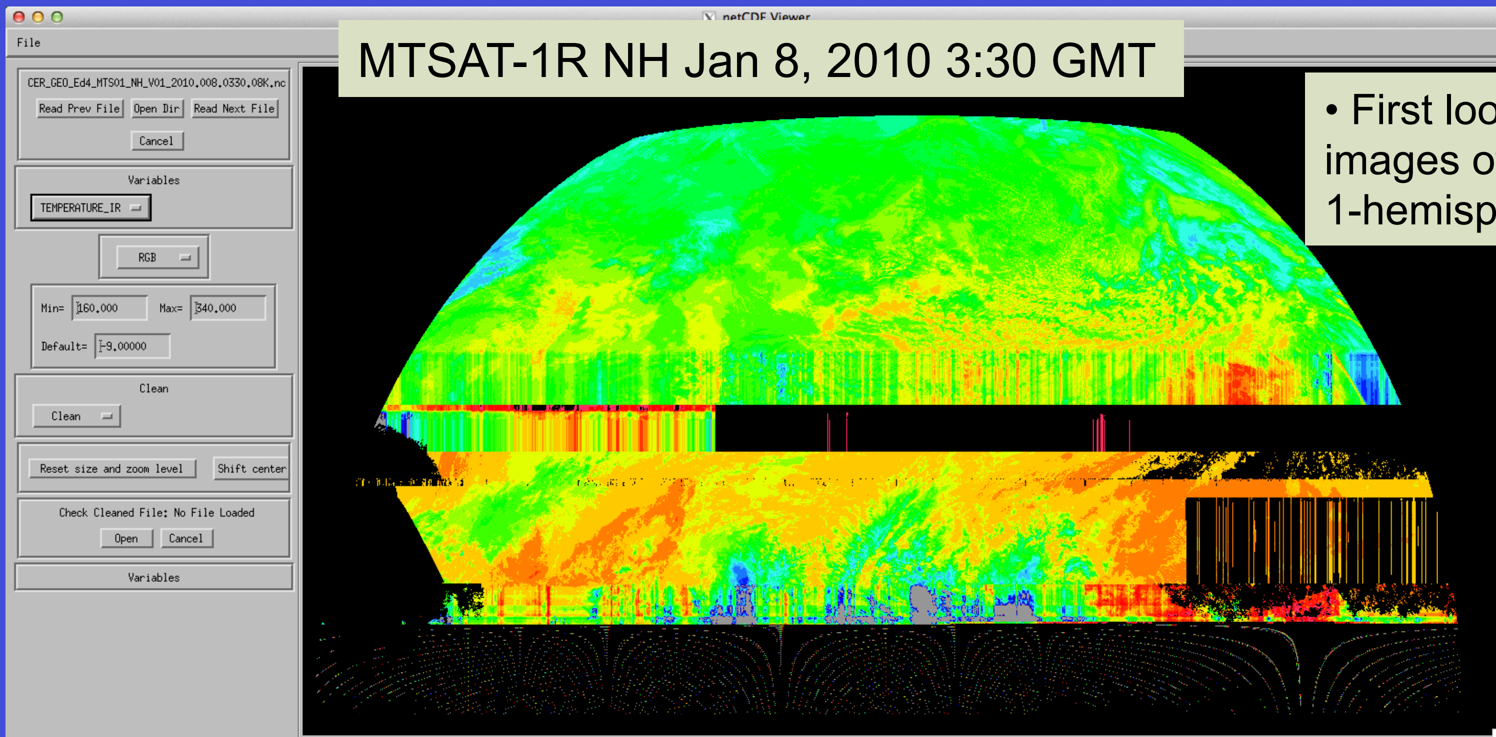
- All normalized CERES-GEO LW flux biases are mostly within ±3% for all methods
- 1-step LW NB to BB has the lowest RMS errors, with or without normalization
- 1-step LW NB to BB has the closest CERES-GEO LW fluxes biases near zero

GEO bad scan line removal

- Ed2 utilizes 3-hourly 2-channel GEO images
  - 16 images per day
- Ed4 utilizes 1-hourly 5-channel GEO images
  - 120 images per day (7.5x as many as Ed2)
  - 7.5x the probability of GEO bad scan lines in data causing cloud retrieval issues
- Current using human visualization to detect and remove bad GEO scan lines
  - takes at minimum ~8 hours/datamonth per person
  - 14 years of GEO data = 0.5 FTEs
  - First detect visually ~7 hours, Second use human GUI interface to remove ~1 hour
  - This process has been greatly improved recently and we have reached the limit of improvement
- Currently developing an automatic technique
  - The issue has always been false positives
  - Have automatic technique find the potential bad images, and utilize the GUI interface to remove only the true bad scan lines

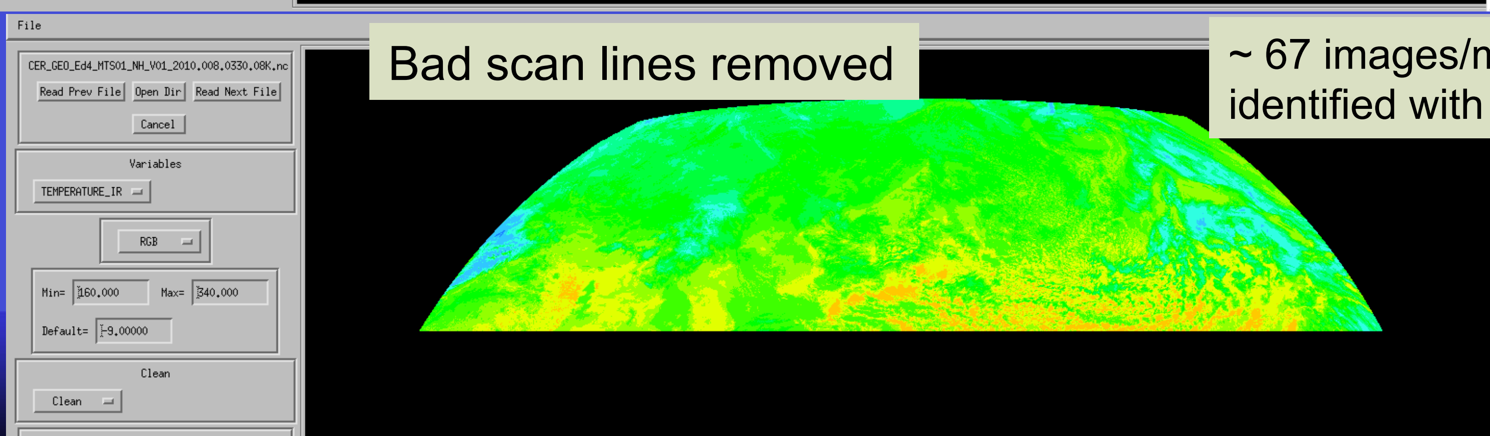
GEO bad scan line removal using IDL GUI interface

MTSAT-1R NH Jan 8, 2010 3:30 GMT



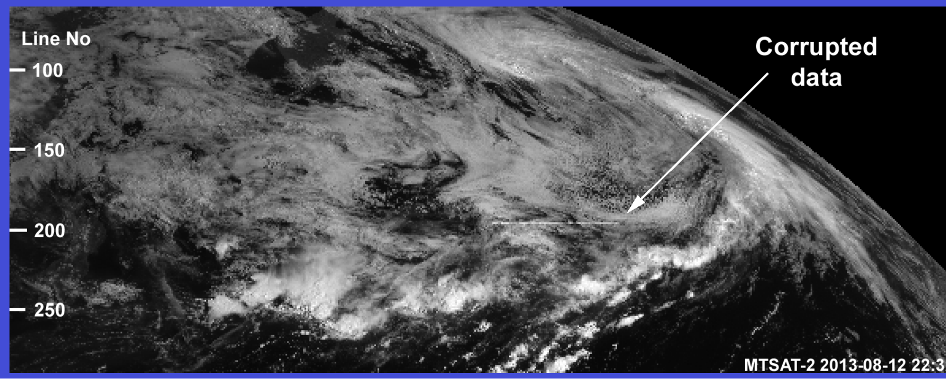
- First loop through 744 images of 1-channel of 1-hemisphere of 1-GEO

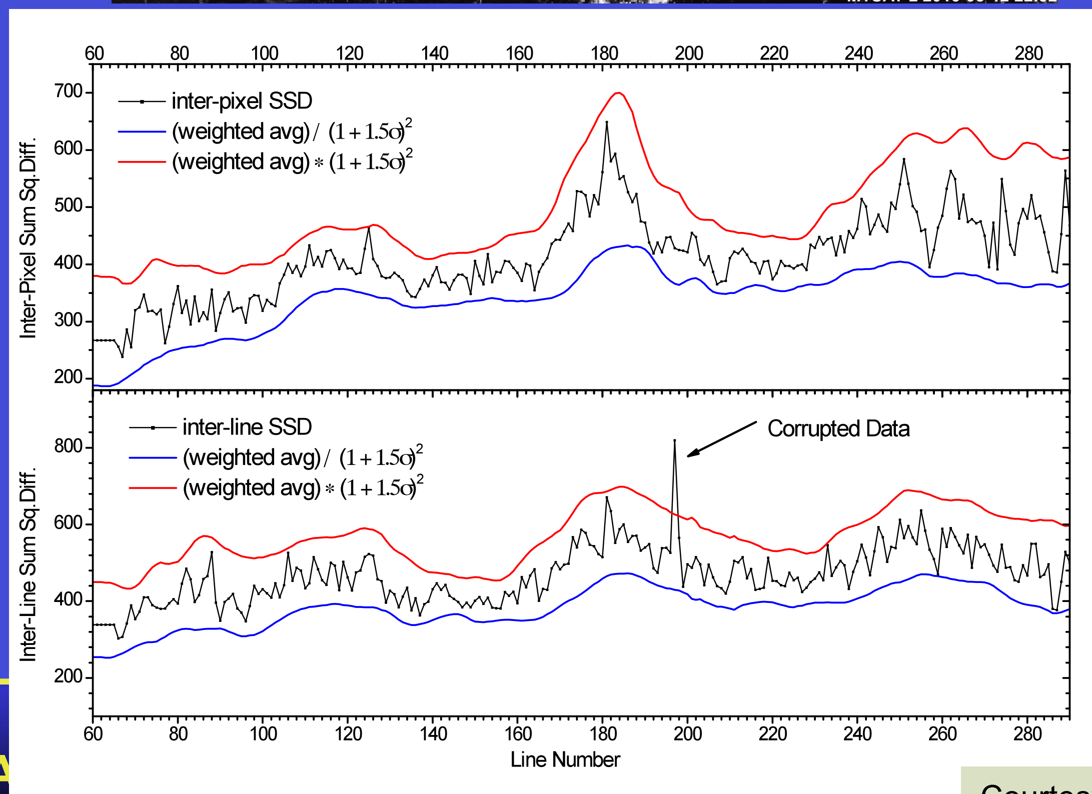
Bad scan lines removed



~ 67 images/month are identified with bad scan lines

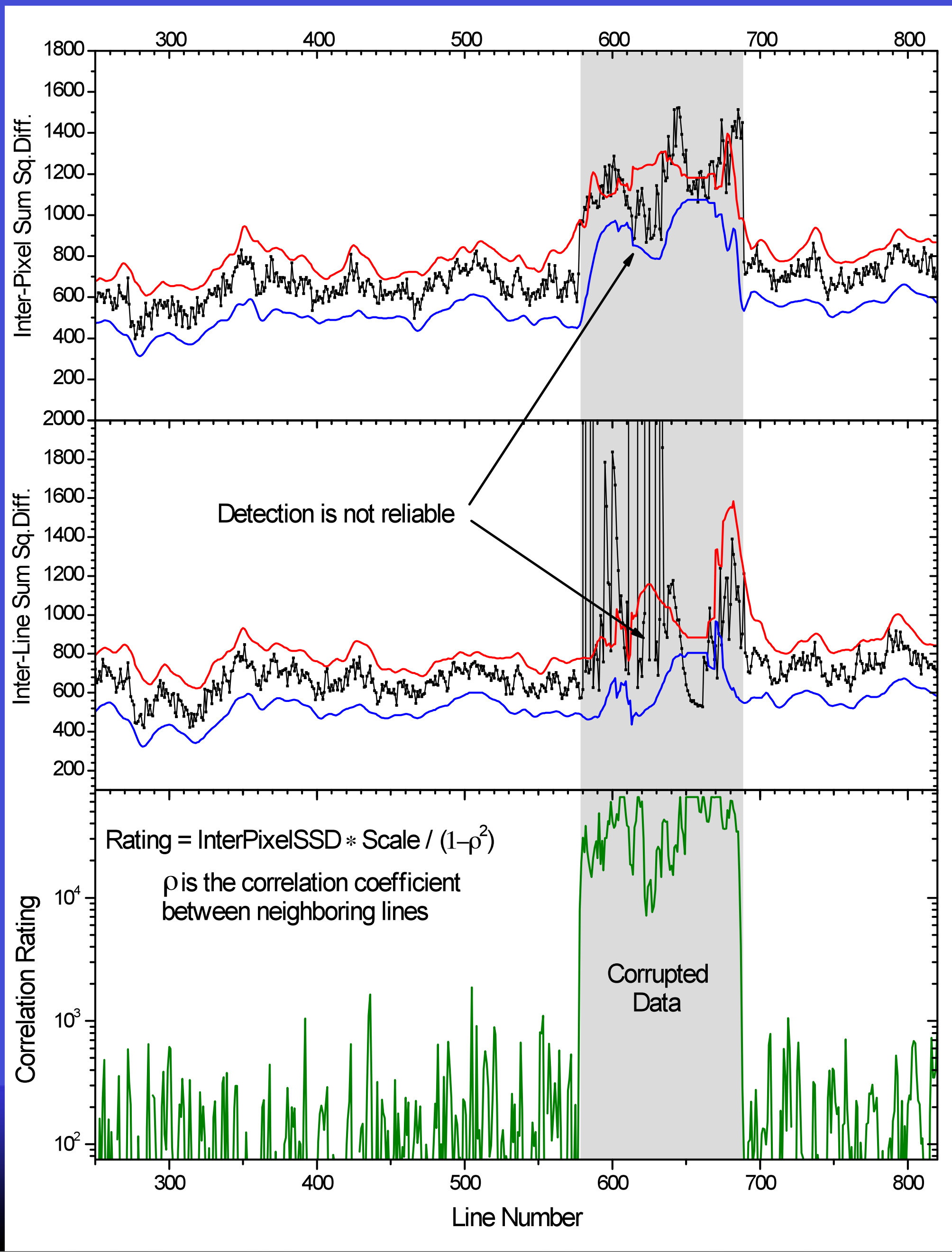
Detection of individual corrupted lines

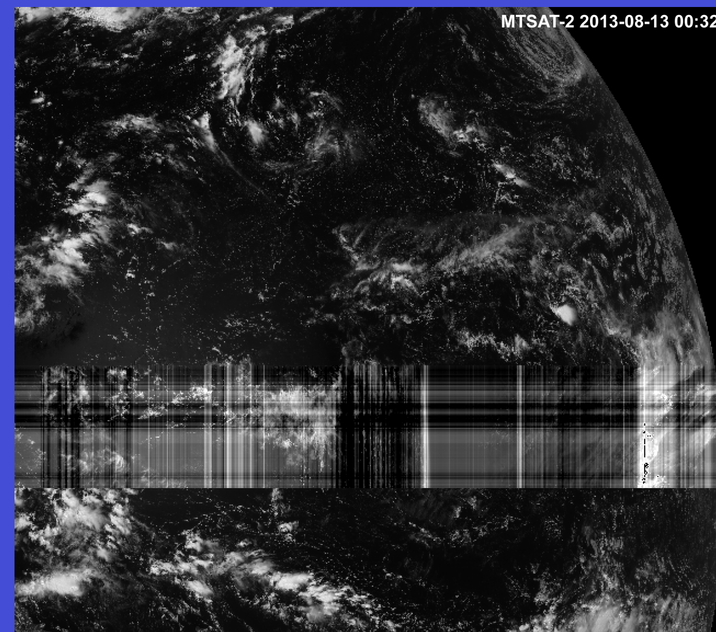




Courtesy of Konstantin Khlopenkov

Using inter-line correlation to detect corrupted blocks of data

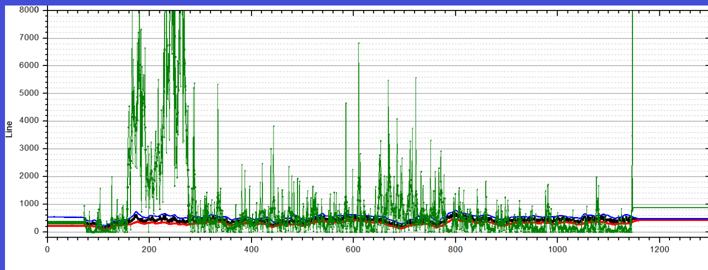




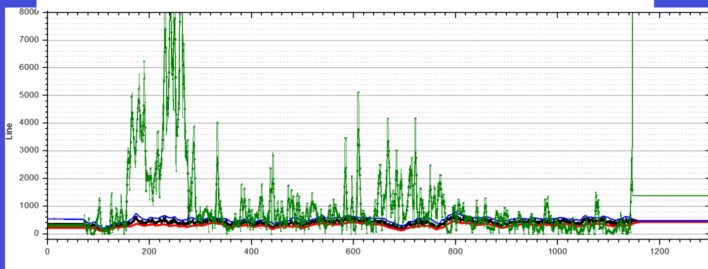
Here, the inter-line and inter-pixel difference tests can fail. This kind of striped noise can be detected by using correlation between neighboring lines.

Courtesy of Konstantin Khlopenkov

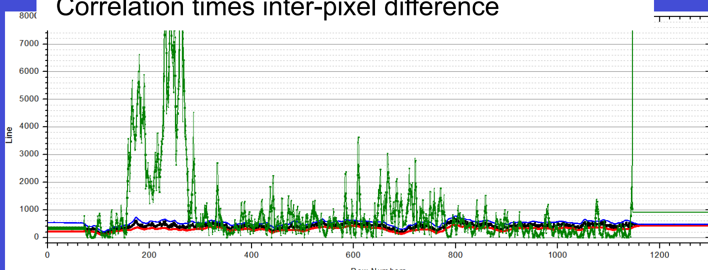
Optimization of the correlation rating



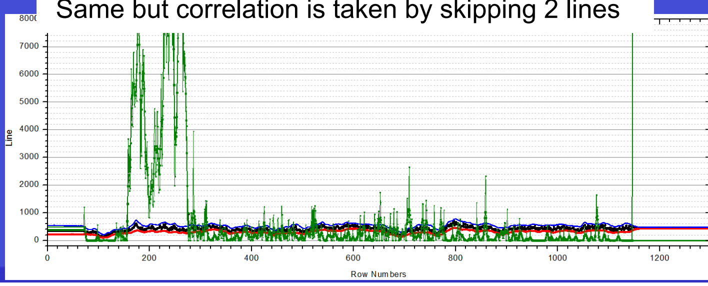
Plain correlation



Correlation times inter-pixel difference

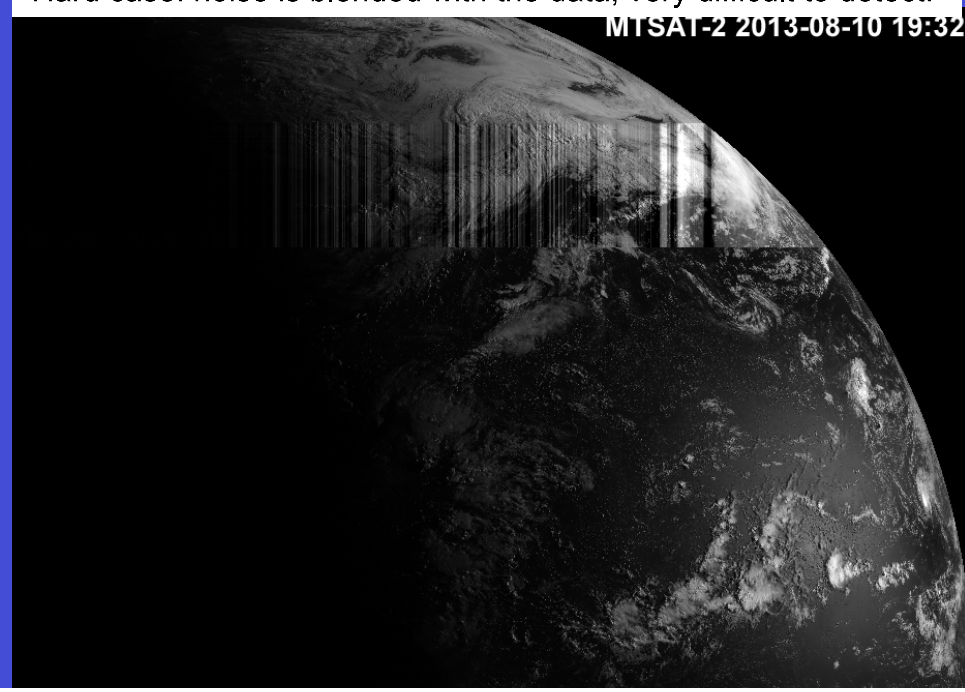


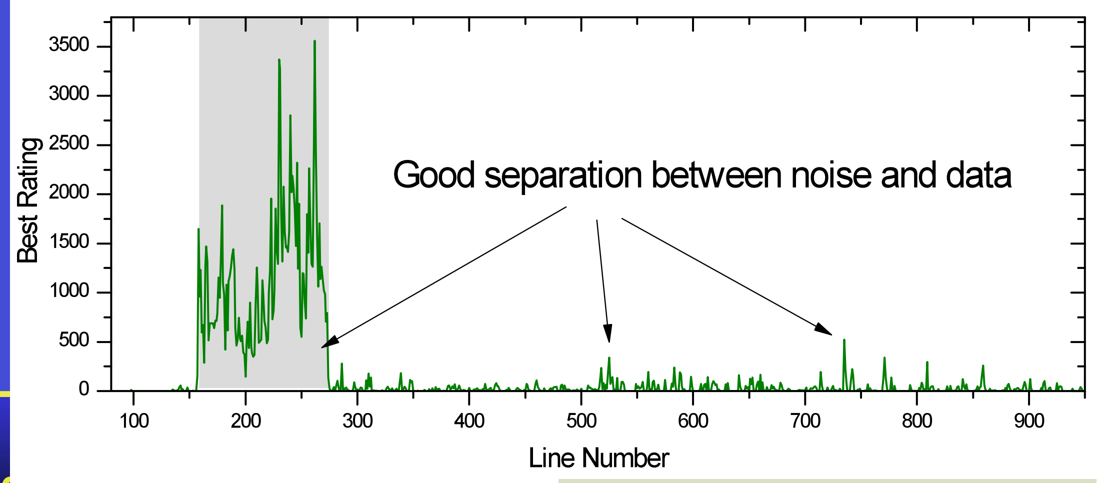
Same but correlation is taken by skipping 2 lines



Most optimal: correlation is taken (a) between ith line and (i-2)th , (b) ith and (i+2)th , (c) (i-1)th and (i+1)th line. The 2 smallest values among a, b, and c are summed together and multiplied by the inter-pixel difference.

Hard case: noise is blended with the data, very difficult to detect:



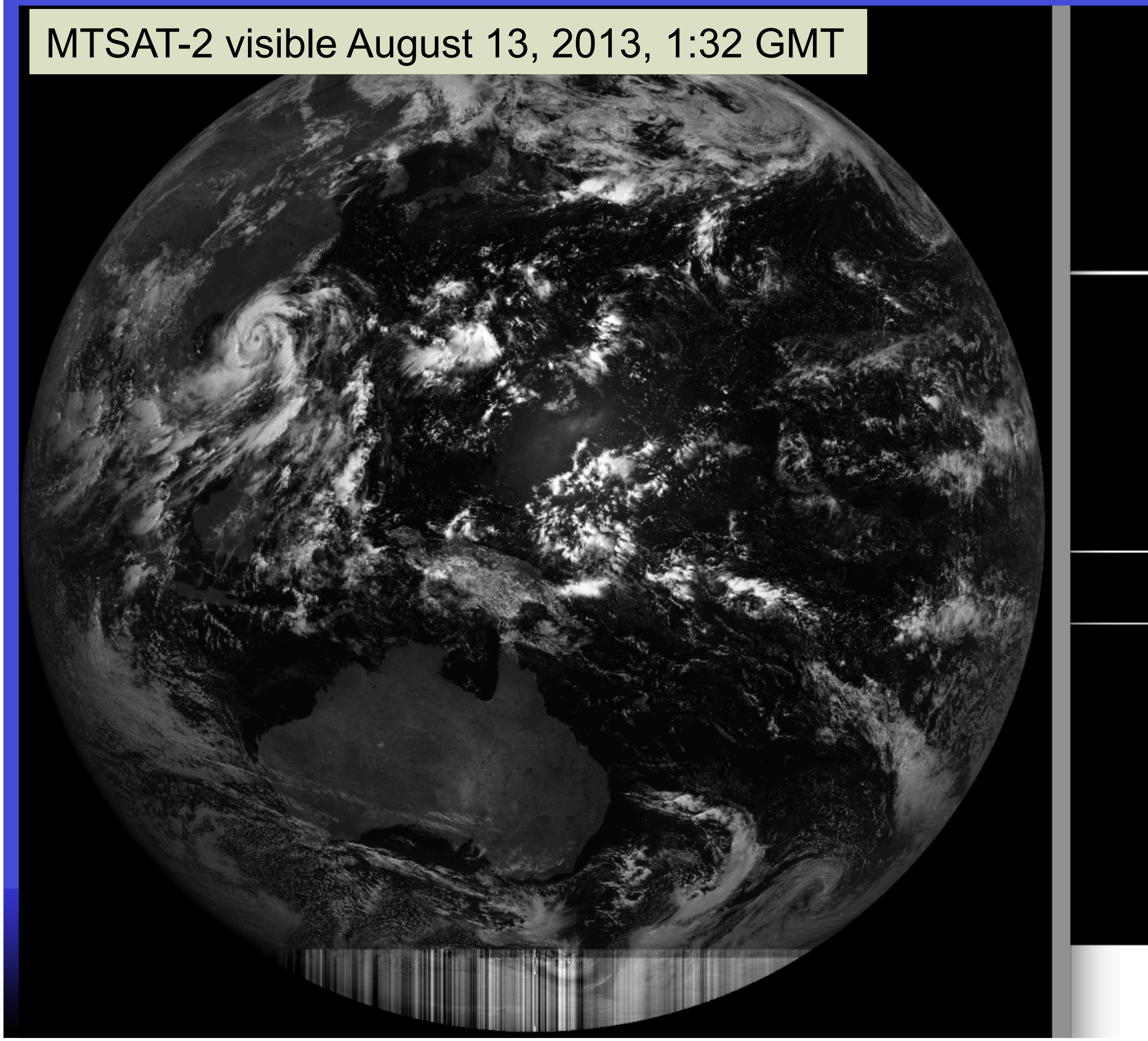


The algorithm uses the most optimal corr.
sigma=8

Courtesy of Konstantin Khlopenkov

Automated routine

MTSAT-2 visible August 13, 2013, 1:32 GMT

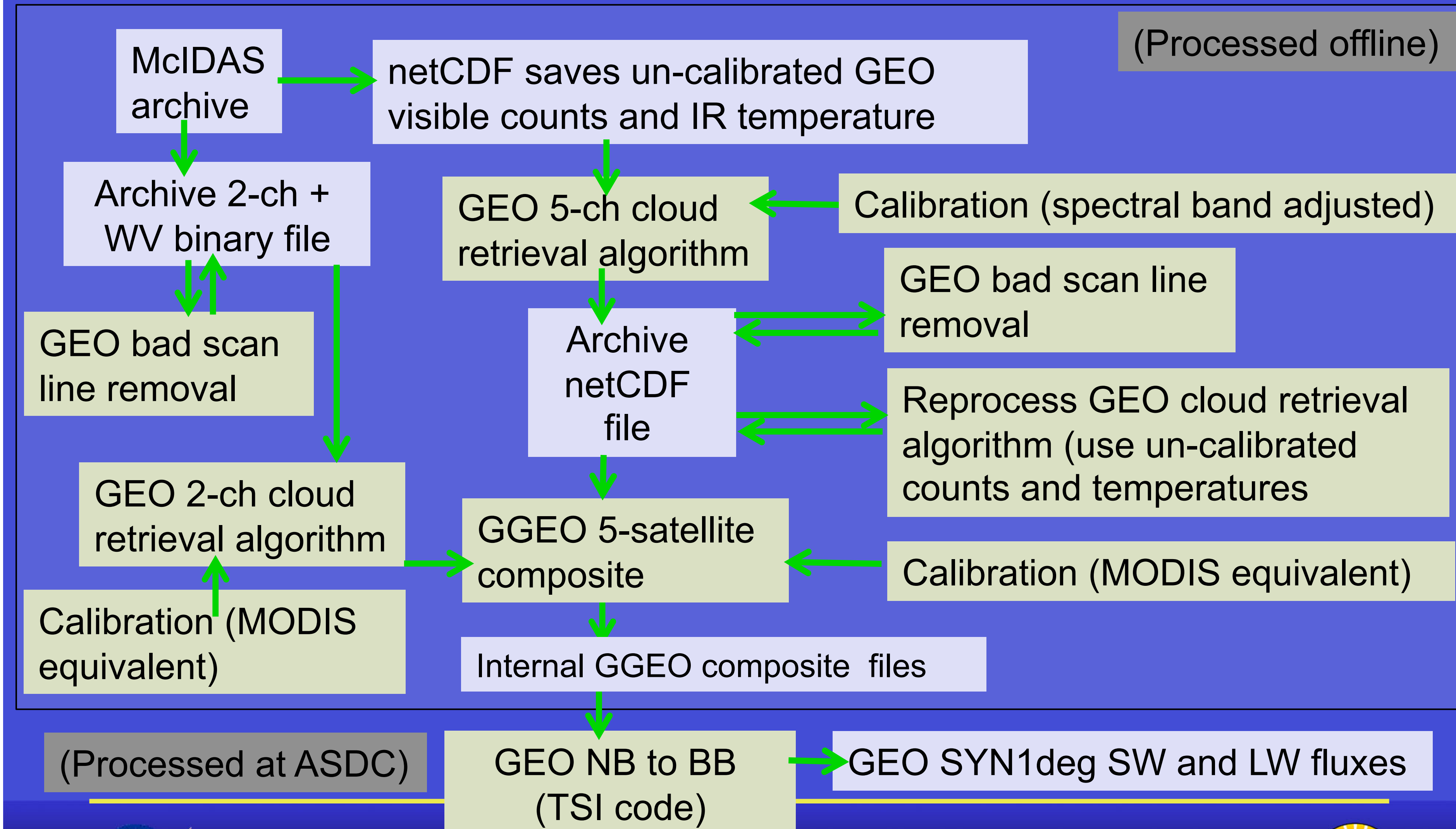


- It is expected that the automated routine will capture all bad scan lines
- Use GUI interface to eliminate only bad scan lines and not any false positives

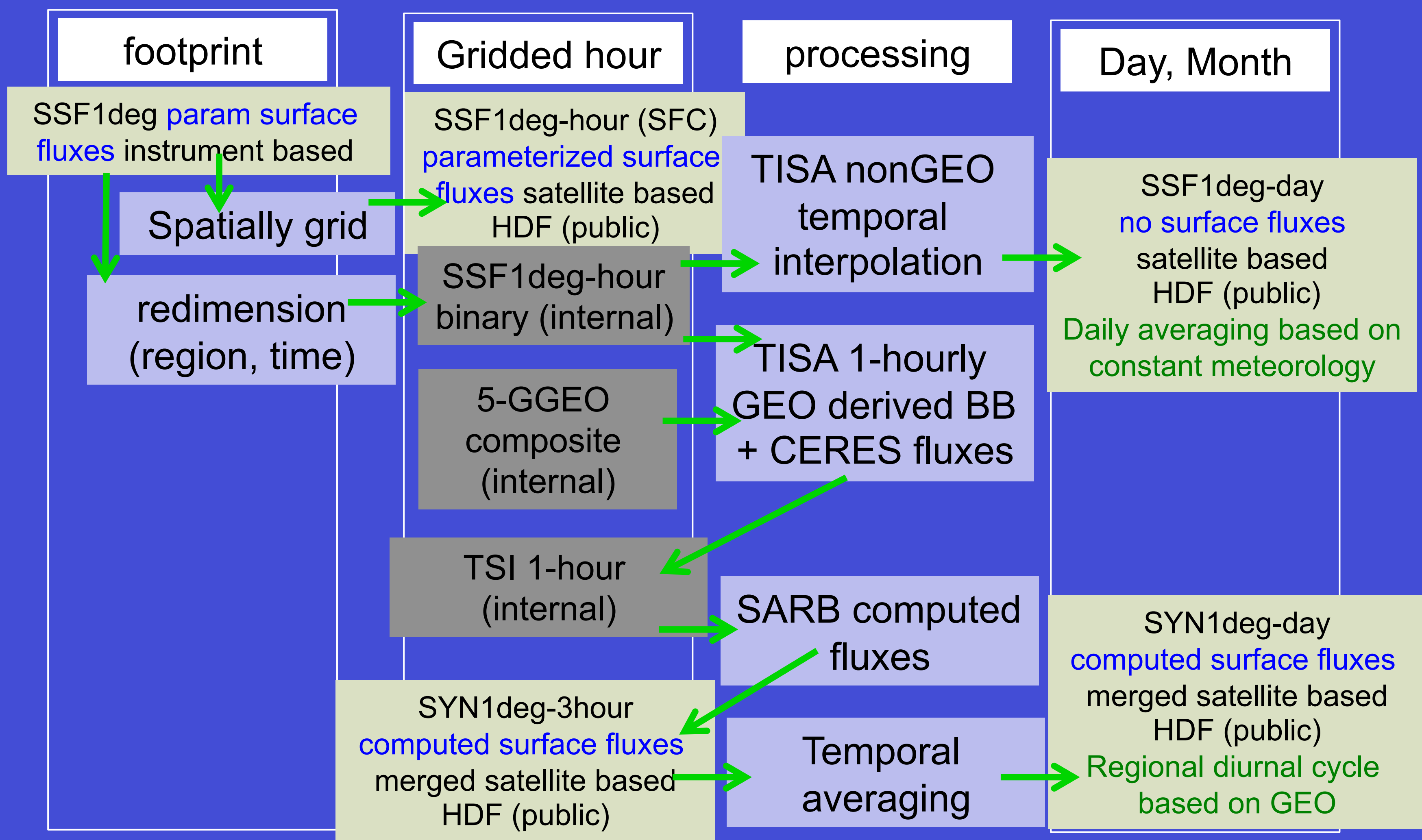
False Positives

Courtesy of Konstantin Khlopenkov

Edition4 GEO processing flowchart

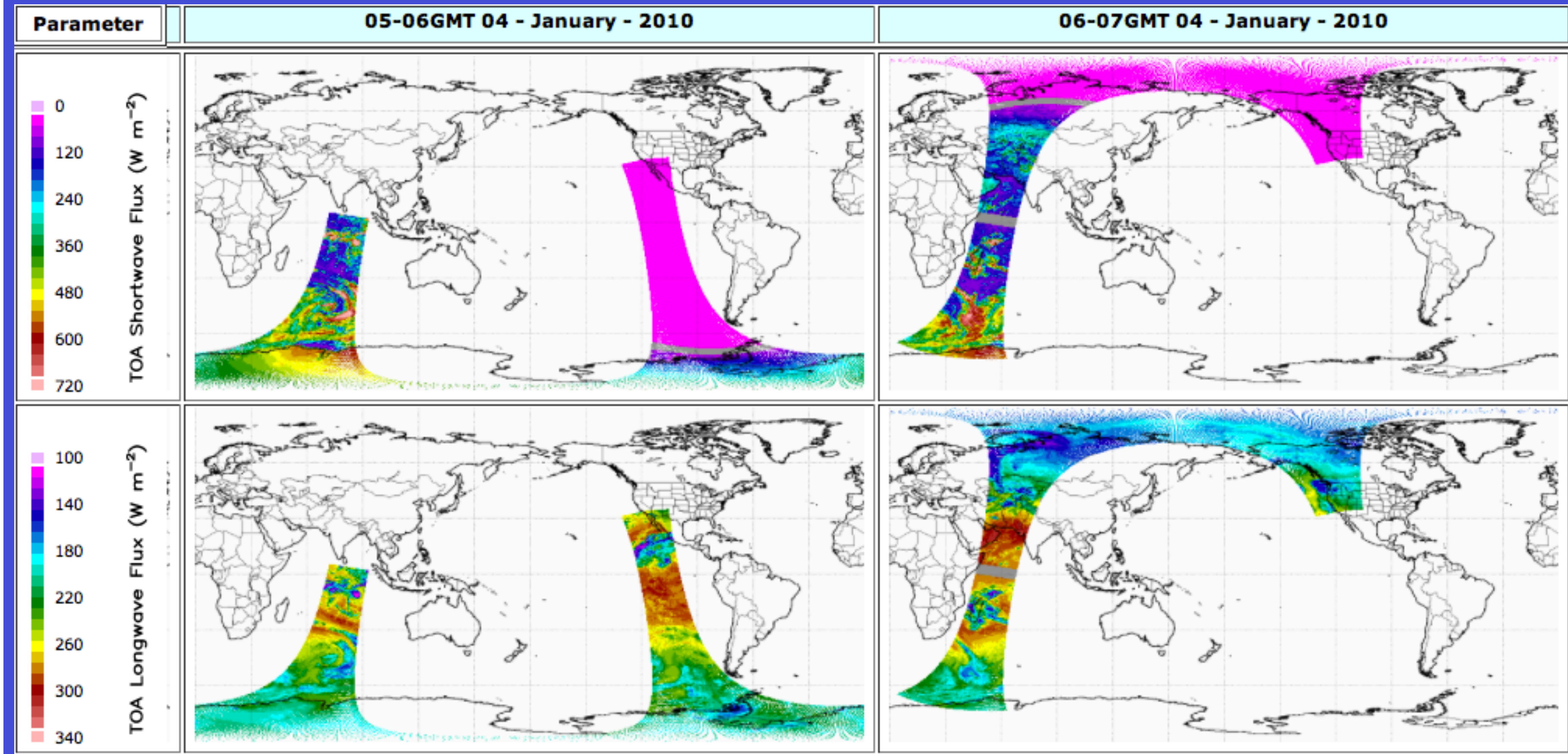


Edition 4 TISA flowchart



- All TISA HDF files will have consistent SSF/SYN unique long and a short SDS names
- Pam is working on SSF1deg-hour/day/month, & SYN1deg-3hour/month DPC and HDF formats

SSF1deg-hour (SFC) HDF (public) Ed4 product



- The number of Ed2 SFC unique users was 6 from Jan. 2013 to the present
- The Ed2 SFC public product was organized by region and then time
- Similar to SSF level-2 the SSF1deg-hour Ed4 will be organized as hourly maps

CERES visualization and ordering

- Feedback from the University or Bergen in Norway
  - Dear Sir/madam, what is the cost of ordering the parameters below, I want to use for education purposes only
  - We were happy to inform, at no cost.
- Ordering tool being tested beyond initial expectations
  - 41 new users in the last two seeks
  - Single orders exceeding 200Gb
  - 10 simultaneous shopping cart orders processed at once
- New visualization
  - CAVE visualization of both SYN1deg computed and observed surface fluxes
  - GGEO composite, GEO netCDF, and MODIS cloud property visualization
- CERES sub-setter order statistics now downloaded daily to EMS
  - All (4-years) historical order statistics have been ingested in EMS
- Worked with ASDC, the CERES web pages, to order through REVERB
  - Implemented level, stream and product information tiers, similar to CERES ordering

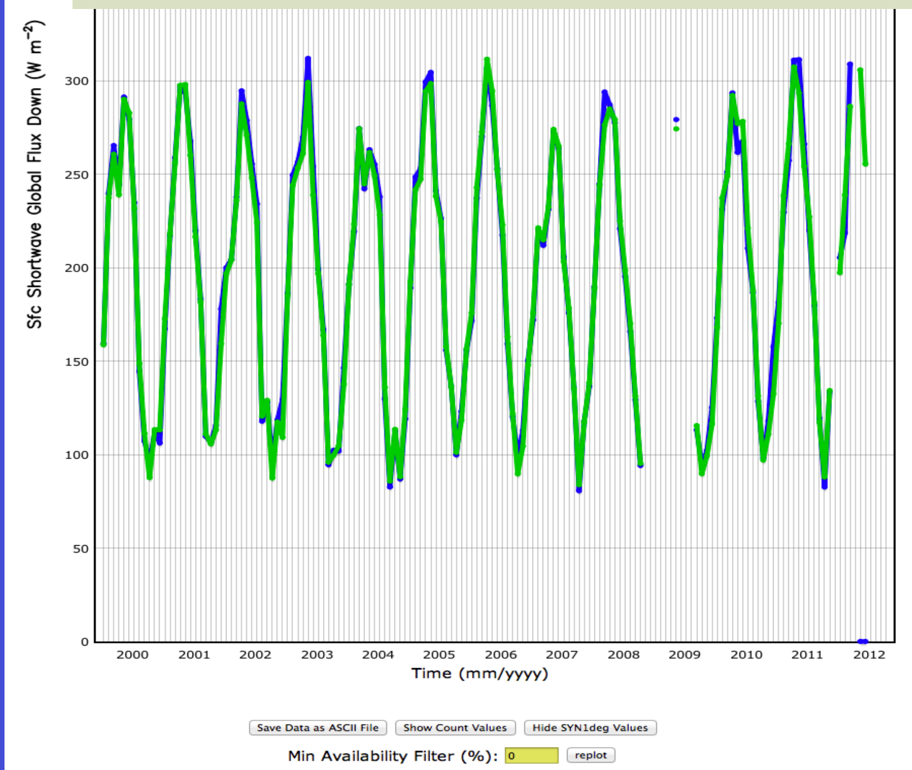
CAVE version 1 visualization

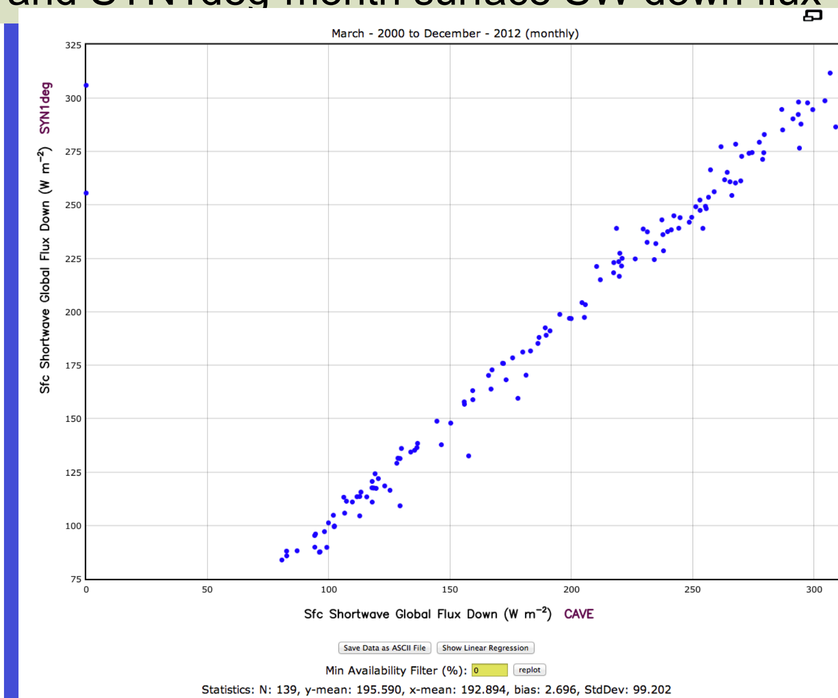
internal users only: http://ceres-tool.larc.nasa.gov/cave/jsp/CAVESelection.jsp

Time series feature

Scatter plot feature

Monthly observed SGP CART best estimate and SYN1deg-month surface SW down flux

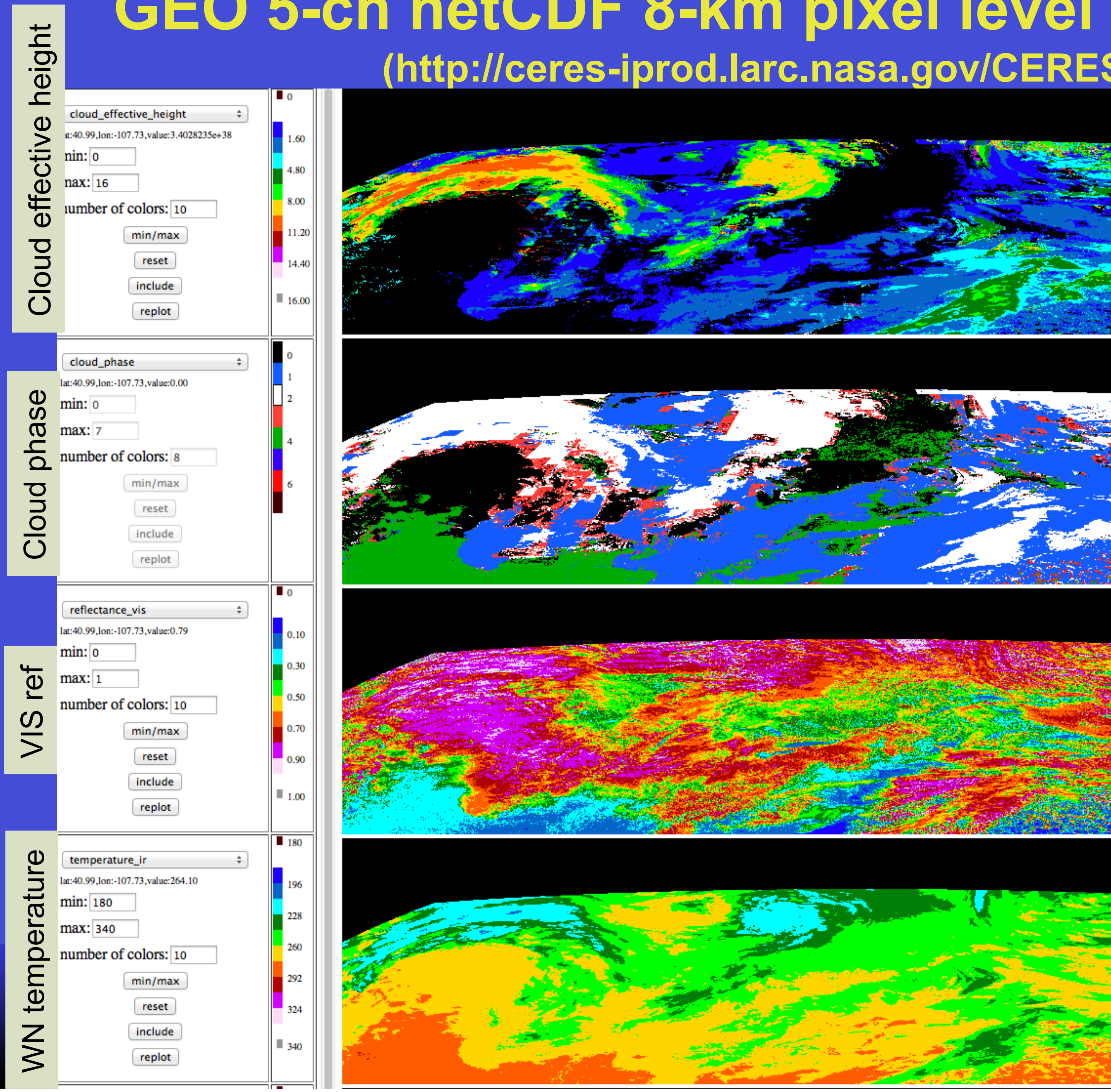




- CAVE web pages have not been promoted to public domain
- CAVE ordering and visualization tool will be public as soon as web pages are

GEO 5-ch netCDF 8-km pixel level visualization

(http://ceres-iprod.larc.nasa.gov/CERESVis/)



- Similar to SSF level 2 visualization
- Mouse over feature to see several pixel level cloud property values
- Easy to find anomalous values

TISA future work

- LW NB to BB Ed4
  - GEO WN+WV radiance method has been fully tested and has been incorporated into Ed4 TSI framework and tested by SARB group
  - Continue to validate with GERB and also validate with Megha-tropique
- SW NB to BB Ed4, direct GEO NB to BB radiance approach
  - Lusheng provided 32 band radiance LUTs as a function of cloud top/thickness, PW and 4 profiles, previously found LUT to have top and PW dependencies
  - Validate by applying NB to BB at Aqua times and validate with Terra
  - Straight forward to incorporate into current TSI framework
- All Edition4 products (SSF1deg and SYN1deg) will be in GMT time
  - Use integrated SZA for simple SW flux averaging rather than GMT snapshots in time
  - Identify small annual global SW incoming flux bias between local and GMT codes
- Deliver the SSF1deg-hour/day/month codes in May 2014
- Deliver the SYN1deg-3hour/month in June 2014
  - Process GEO 5-ch cloud properties and remove bad scan lines over summer
- Place new products on CERES ordering tool
- Deliver ISCCP-D2like and fluxbycloudtype Ed4 products in Fall 2014